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HOTCHKISS MACHINE REVOLVING CANNON.

THE 37-millimeter naval gun is carried on a coned support, the pivot, to which the trunnion bearings are attached, fitting into a socket on the top of the steel plate cone that is fastened to the deck by bolts passing through the flange; or the same pivot can be set in a bracket socket bolted to the rail of a ship, or other convenient place. The landing carriage for this gun resembles an ordinary field carriage, except that it is provided with a socket instead of the usual trunnion bearings. The 47-millimeter revolving gun is too heavy for landing purposes, but its ship mount is similar to that of the 37-millimeter. The boat carriage (see Fig. 1) is altogether of a different type, consisting of a bedplate mounted on rollers for fore and aft traverse, with a pivot bolt for fixing at either end, and a central pivot. Upon this pivot is placed a carriage, the rear of which is provided with traverse gear connected with the bedplate. Training is effected by screw elevating gear.

Fig. 2 illustrates a special type of gun, of which considerable numbers have been made by the Hotchkiss Ordnance Company. It is especially designed for flank defense, and its special characteristics are set forth in the publication of this company, from which we summarize the following particulars. The object of this gun is to protect trenches, ditches, and other fortification works, by being able to sweep the whole length, and as far as possible the width, of the ditch with a continuous discharge, the gun itself being mounted sufficiently high to prevent an attacking force from masking the embrasure. Ordinary field guns are not adapted for this work, since they can only cover a narrow area; mitrailleuses and similar guns are insufficient, since without special arrangements they cannot cover the required space.

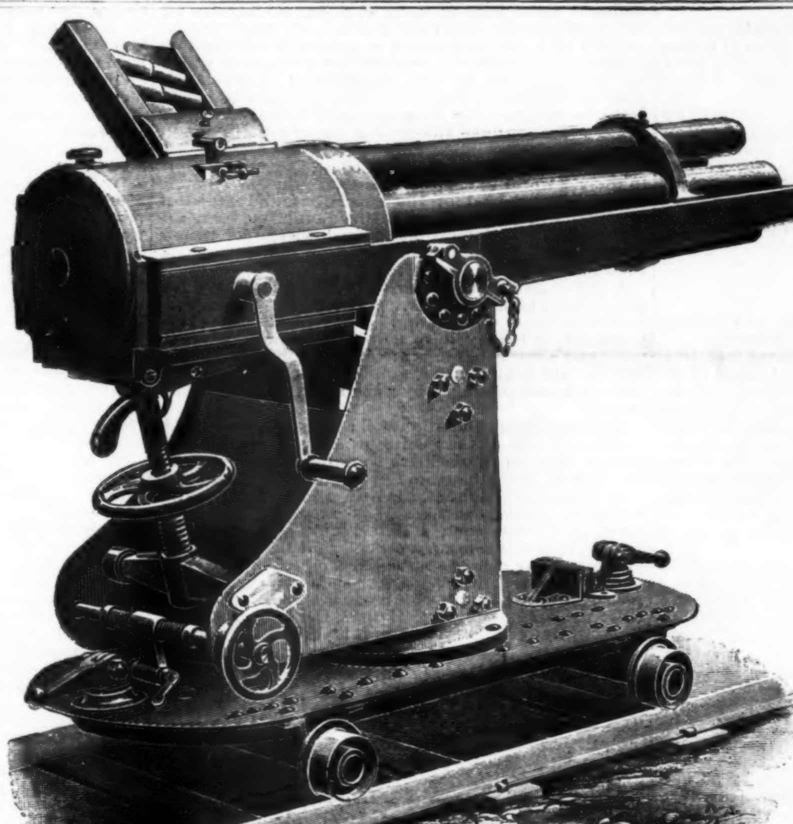


FIG. 1.—47 MILLIMETER HOTCHKISS REVOLVING CANNON.

The principle on which the flank gun is designed is as follows: "If from a rifled gun a round of case shot be fired, the canister containing balls of equal shape and size symmetrically disposed about the axis of the projectile, and if this round of case takes the rifling of the bore, remaining whole until the moment of leaving the muzzle, the balls will spread in a cone, whose angle at the summit depends upon the pitch of the rifling, and the general form of the curve of the trajectory of each bullet. The elements may therefore be computed. Let A A′ (Figs. 3 and 4) be the trace of the ground, supposed horizontal, in the vertical plane passing through the axis of the gun, A B being the height of the center of the bore above the ground, and B O being the direction of the axis of the piece inclined at an angle, X, from the horizontal, B H. Let the pitch of rifling be such that the tangents at the origin of the trajectories of each bullet make with B O an angle, Y. Leaving out of consideration the distance of the center of gravity of each bullet from the axis, B O, which may be neglected practically, it is seen that the bullets form a cone whose vertical projection is *a* B *e*, B *d e* being assumed as the trajectory of a single bullet.

"The intersection of this cone with the ground gives a horizontal projection in the form of the complete elongated curve, *a i e k a*. The intersection of the same cone with the plane of defilement, *c d*, drawn parallel to the ground at a height of 6 ft. gives a horizontal projection in the form of the curve, *c i d k e*, similar to *a i k a*. The space swept at a height of less than 6 ft. by the balls of the cone *a* B *e*, that is to say, the dangerous cone of this zone, projected horizontally, is represented by the shaded surface comprised by *i e k* and *i a k* on one side and *i e k* and *i d k* on the other.

FIG. 2.

FIG. 5.

HOTCHKISS REVOLVING CANNON AND AMMUNITION FOR FLANK DEFENSE.

"When, therefore, the height of the gun above the ground is superior to that of the plane of defilement relative to infantry, the dangerous zone of the cone of dispersion is divided into two parts of the form of elongated crescents, touching by the ends of the horns. A second gun barrel placed in exactly the same position as the first, but the pitch of whose rifling is so arranged that the tangents at the origin of the cone of dispersion makes with the axis, B O, an angle, Y, would give a cone *a'* B *e'*, whose dangerous zone projected horizontally would be represented by the shaded surface *i c k a i, i e k d i*. It is readily perceived that by properly arranging the pitch of rifling of this second gun barrel, the surface of the dangerous zones may be made to touch; and by introducing a number of barrels with different degrees of pitch of rifling, a succession of zones may be created, one inside of another, so as to sweep thoroughly the whole space under consideration."*

This is achieved by modifying the Hotchkiss revolving gun, only so far as giving a different pitch of rifling to each barrel, and to mounting the piece with a fixed angle of inclination determined by the height, A B, of the line of fire above the bottom of the ditch. The variations in the pitch of the rifling are determined by the mean length and width of ditch, and the mean height of the line of fire. Once fixed in position, the gun may be considered permanent. The form of rifling adopted comprises twelve grooves with a constant pitch, as follows:

Barrel No. 1.	One turn in	1	meter (39·37 in.)
" " 2.	" "	1·34	"
" " 3.	" "	2·20	"
" " 4.	" "	3·50	"
" " 5.	" "	6·70	"

Two men are required to work the gun, one feeding the cartridges and the other turning the crank.

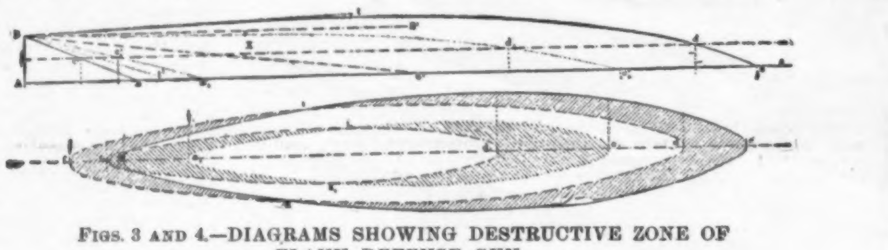
The carriage on which the gun is mounted is of iron with parallel side frames, and the effort of recoil is resisted by anchoring the carriage with pickets, and by friction brakes on the centers of the wheels. A special detail is introduced for feeding the guns with the large number of cartridges required at critical moments: this is a distributor placed on the left-hand side of the gun, and to which movement is given by the combined action of the elevating screw and the revolving crank; by the arrangement adopted the feeding mechanism follows all angles of direction and elevation given to the gun, and a regular feed is secured.

To complete its destructive character, the projectiles employed are shrapnel (see Fig. 5), the metallic cartridges are charged with 1·18 oz. of powder, joined to a metal box holding 24 balls of hard lead 0·71 in. in diameter, arranged in eight tiers of three balls each, and with the interstices filled with sawdust; the bottom of the box, made of a loose iron plate, forms at short ranges a formidable projectile. The normal rate of firing is 60 rounds a minute, 1,500 dangerous projectiles, all of which are concentrated with a narrow zone; the speed can, however, be raised to 90 a minute, corresponding to 2,250 projectiles in the same time. The following are some of the leading particulars of this gun, its carriage and ammunition:

Revolving Gun for Flank Fire.

Weight of gun	1,161·6	lb.
Length "	70·47	in.
Weight of carriage and shield	1,452	lb.
Height of trunnions	47·24	in.
Weight of cartridge	2·42	lb.
Total length of cartridge	8·11	in.

—*Engineering.*



Figs. 3 and 4.—DIAGRAMS SHOWING DESTRUCTIVE ZONE OF FLANK DEFENSE GUN.

GASEOUS ILLUMINANTS.†

By Prof. Vivian B. Lewes.

I.

Although born scarcely a century ago, our gaseous illuminants have made such strides within the last ten years that I feel I need no excuse for taking them as the subject of this course of lectures, and in doing so I propose to treat more especially the new processes which are making their mark in the gas world, and, as far as the subject will allow, to omit those which are either obsolete or are gradually being superseded.

Just 200 years after Van Helmont (in the 17th century) first used the term "gas" to describe aeriform bodies, Faraday defined a gas as being the vapor of a volatile liquid existing at a temperature considerably above the boiling point of the liquid, and stated that the condensing point of the gas is merely the boiling point of the liquid producing it. This definition was at the time contested, as several of the gases had not then been condensed; but at the present time we know that the condensation of any gas to the liquid form is merely a question of sufficiently intense cold and pressure.

At ordinary temperatures, for instance, carbon dioxide, or carbonic acid gas, is as good an example of an aeriform body as one could adduce, and is recognizable only from air by its physical and chemical properties, but subject the clear, colorless gas to a temperature of — 78·2° C. and it condenses to a clear limpid liquid which might easily be mistaken for water, and which, if the temperature is again allowed to rise to 0° C., requires a pressure of 36 atmospheres, or 15 × 36 pounds on the square inch, to prevent it assuming once more the gaseous form; release it from this pressure, and it at once again becomes gaseous, and in doing so absorbs so much heat that a temperature of close upon —100° C. is produced, while some of the liquid is frozen into the solid form. This shows that the state of aggregation of the body is dependent upon the existing temperature.

In the solid and liquid states, the particles or molecules of which all matter is built up are to a certain extent checked and limited in their vibrations by the force we know as cohesion, but in the gaseous state the particles have freed themselves from this restraining force, and being able to mingle freely with other gaseous molecules, are in a condition highly favorable to the production and carrying on of chemical combination.

Gases containing hydrogen, compounds of hydrogen with carbon, and compounds of these two with other elements, have most of them so strong an affinity for the oxygen contained in our atmosphere, that the heat emitted by a burning match is generally sufficient to determine combination between the gases, and where the heat evolved by the combination between the gases is sufficient to raise the gases or vapor to incandescence, we have the phenomenon of flame.

Some flames have the power, under certain conditions, of emitting light, while others have no photometric value, and it is a matter of the gravest import to the gas world that as clear a conception as possible should be obtained of the conditions and cause of luminosity in flame, as until this point has been definitely fixed, it is impossible to lay down the conditions under which our illuminants must be burned to yield their maximum lighting effect.

A visible flame may either be solid, *i. e.*, composed of a solid mass of incandescent particles, as when a mixture of nitrogen dioxide and carbon bisulphide vapor is ignited, or it may have a distinctive internal structure, and show zones in which varying phases of combustion are taking place, and it is to this latter class that all flames produced by a gas issuing from a burner belong.

A moment's consideration will at once make it manifest that if one gas is issuing in a steady, continuous stream into an atmosphere containing the gas with which it is to combine, and if combination is set up, *i. e.*, if the gas is lighted, the action can only go on for a limited space from the surface where the two gases meet, and hence such a flame must of necessity be hollow, and will contain a central zone in which entire absence of air causes absence of combustion, an intermediate zone in which partial combustion is taking place, a limited supply of air being able to penetrate; this zone is, in practically all cases, the light-producing zone, while outside this again it is just possible to discern an envelope of non-luminous flame where the excess of air destroys all luminosity, for reasons which will later be discussed. Careful examination also shows that the flame is not in contact with the rim of the burner from which the gas is issuing, this space being claimed by some observers as constituting a fourth part.

In the "Philosophical Transactions" for 1817, Sir Humphry Davy propounded his celebrated theory that the cause of luminosity in flames was the incandescence of nascent carbon, a theory which has always been accepted as the true one, until the researches of Dr. Frankland, in 1868, on the effect of pressure on non-luminous flames showed that under certain circumstances, never likely to occur in a gas flame, luminosity might be due to other causes, while still later observers have shown that luminosity in a flame is to a great extent affected by temperature. These factors, although of the greatest importance, do not affect the truth of the original theory.

In the last contribution to the subject, Davy's theory is attacked by Mr. F. J. Rowan, in a paper on "Flame," read before the Society of Chemical Industry, in 1889; and, inasmuch as his paper was reprinted in full in the *Journal of Gas Lighting*, as well as in the *Journal of the Society of Chemical Industry*, and hence found its way into the hands of very many who are interested in gas lighting in the kingdom, I think it will be of interest to fully discuss a question of such vital importance to the gas industry before passing on to other branches of the subject.

In the introduction to an article on "Some New Researches on Flame," published in the "Philosophical Magazine," in 1817, Sir Humphry Davy says, while alluding to a paper published in one of the early numbers of the *Journal of Science and the Arts*, "I have given an account of some new results on flame which shows that the *intensity* of the light of flames depends *principally* upon the production and ignition of solid matter in combustion," and it is round this statement that the battle of luminosity has raged, the word *principally*, however, being lost sight of, and the theory being more often propounded as "the presence of solid particles suspended in the flame (or in immediate contact with the burning gas) is *essential* to its luminosity."* An idea which Davy never had, as is shown by his later paper defining flame as follows: "Flame is a gaseous matter heated so highly as to be luminous;" and again, "When in flames pure gaseous matter is burnt, the light is extremely feeble." Moreover, he alludes to "common flames," evidently meaning the flames of candle, lamp, or gas, in all which cases I think it can be proved beyond a doubt that his theory as expounded by himself was perfectly correct.

On June 11, 1868, Professor G. Frankland read a communication before the Royal Society in which he describes experiments which led him to doubt Sir Humphry Davy's theory. He points out that the deposit of soot formed when a cold surface is held in a gas or candle flame is not pure carbon, but contains hydrogen, which can only be got rid of by prolonged heating in an atmosphere of chlorine. Also, that many flames possessing a high degree of luminosity cannot possibly contain solid particles.

Arsenic burnt in oxygen gives a bright white light, yet as arsenic volatilizes at 180° C. and the arsenic trioxide formed at 218° C., it is evident that at the temperature of incandescence, which is at least 500° C., there can be no solids, but simply vapor, present in the flame. For the same reason the intense light due to burning phosphorus in oxygen cannot be explained by the solid particle theory. From these results Dr. Frankland considers that "incandescent particles of carbon are not the source of light in gas and candle flames, but that the luminosity of these flames is due to radiations from dense but transparent hydrocarbon vapors." And he further shows that the non-luminous flames, such as those produced by carbon monoxide and hydrogen, can, when burning in an atmosphere of oxygen, be rendered luminous if the ordinary atmospheric pressure is increased to 10 atmospheres, so as to prevent or retard as far as possible expansion during combustion. From Professor Frankland's experiments there is no doubt but that the luminosity of a flame is increased by pressing around it the atmosphere in which it is burning, and also that rarefaction has the opposite effect, a point also worked out by Davy, but his experiments do not show that incandescent particles of carbon are not the principal source of luminosity in a gas flame. He also shows that the higher the density of the vapors present in a flame, the more likely is it to be luminous.

In 1874, Soret attempted to demonstrate the existence of solid particles in a luminous hydrocarbon flame by focusing the sun's rays on the flame, and examining the reflected light by means of a Nicol's prism, but neither his research nor that of Burch, who repeated his experiments, using the spectroscope instead of the Nicol's prism, show more than that solid particles are present.

W. Stein ("Journal of Pract. Chem." [2], viii., 402) in considering Frankland's objections to Davy's theory points out that the soot which is deposited from a candle or gas flame, and which Frankland looks upon as a condensed hydrocarbon, contains 99·1 per cent. of carbon, and only 0·9 per cent. of hydrogen, which is about the amount of hydrogen one would expect to be occluded by carbon formed under these conditions, and he also points out that if the soot were a heavy hydrocarbon condensed by a cold surface cooling the vapor in the flame, then it ought to again be volatile at a high temperature, which it is not.

The next steps in the controversy were the attempts made by Hilgard ("Annalen der Chemie," lxxxxii. 129), Landolt ("Poggendorff's Annalen," lxxxxix. 389), and Blochman ("Annalen de Chemie," clviii. 295) to trace the actions taking place in various flames by withdrawing the gases from various parts of the flame, and determining their composition, experiments which enable one to form an idea of the changes taking place in the various parts of a luminous flame. Ordinary 16 to 17 candle coal gas as supplied in London may roughly be taken as consisting of:

Hydrogen	51·6
Marsh gas or methane	36·7
Illuminants	5·8
Carbon monoxide	5·1
Carbon dioxide	0·0
Nitrogen	0·6
Oxygen	0·2
	100·0

Of these, the last three only exist as traces, and play no part in the combustion, while of the remainder it is found that the hydrogen burns most rapidly, then the carbon monoxide, and next the marsh gas, while the illuminants are the slowest to burn; but when at the bottom of the flame hydrogen and carbon monoxide enter into a non-luminous combustion, forming water vapor and carbon dioxide with the oxygen of the air, they have by no means completed their function, as the aqueous vapor passing upward through a zone of intense heat becomes again dissociated to a certain extent into hydrogen and oxygen, while the carbon dioxide coming into contact with incandescent carbon, liberated from the heavy hydrocarbons forming the illuminants, becomes again reduced to carbon monoxide, these only finally completely recombining to saturated products of combustion in the outer non-luminous zone of the flame. Landolt took an ordinary rich coal gas flame, 3½ in. in height, and traced the changes taking place by withdrawing the gases in the flame at various points from the orifice of the burner up to about two inches above it, with the following results:

Composition of Gas in Flame.	Height from Burner in Inches.					
	0	9·39	0·79	1·18	1·58	1·97
Hydrogen	22·66	14·95	15·49	15·44	14·50	11·95
Marsh gas	33·77	30·20	28·34	21·55	11·92	3·64
Carbon monoxide	7·34	14·07	14·05	14·58	22·24	25·14
Olefines	7·29	7·49	7·87	7·49	7·05	5·45
Oxygen	0·66	0·78	0·47	...	...	...
Nitrogen	29·41	38·66	140·78	184·23	270·45	307·10
Carbon dioxide	1·94	92·34	10·11	14·98	23·76	32·34
Water	8·34	11·60	38·85	52·55	72·67	75·61

He used a gas containing a high percentage of illuminants, and on examining his results we see that the hydrogen is the first to burn, as one would expect from its relatively low igniting point and great rapidity of combustion. The burning of the carbon monoxide cannot be traced in the same way, as it is formed more rapidly by the incomplete combustion of the marsh gas that it burns, so that a steady increase in the proportion takes place, while the marsh gas steadily burns away until a height of 1⅛ inches is attained, when its combustion becomes very rapid.

The illuminants practically undergo no change at first, indeed they slightly increase in quantity from the decomposition by heat of some of the marsh gas into acetylene; and they only begin to decompose at a height of 1⅛ inches above the orifice of the burner, and then burn rapidly in the highest part of the flame.

A most important fact, moreover, to be noted is that

* "The Hotchkiss Revolving Cannon." Printed for private circulation.

† Lectures recently delivered before the Society of Arts, London. From the Journal of the Society.

* The italics in all cases are mine.—V. L.

at the height of 1⅙ inches there is a sudden rise in the quantity of carbon monoxide at the moment that the illuminating olefines begin to disappear—a result undoubtedly due to the action of the nascent ignited carbon on carbon dioxide.

Among the illuminants are several hydrocarbons, the probable composition of which will be discussed in the next lecture, and these are gradually broken down in intermediate stages in the lower part of the flame, until finally they become marsh gas and carbon, and it is this carbon which in excessively minute particles at the moment of liberation is heated to incandescence, and "principally" gives the light of the flame. The marsh gas originally present and also that formed from the heavier hydrocarbons adds its iota to the luminosity by still further decomposition during combustion, before finally being carbon dioxide and water.

In 1876, Dr. Karl Heumann made most important contributions to the theory of luminous flames in some papers published in "Liebig's Annalen," vols. clxxxi. and clxxxii., in which he carefully goes over the work of previous observers, and by a large number of original experiments proves that Davy's theory was correct, but that other causes also affected the degree of luminosity in a gas or candle flame.

In the ordinary atmospheric burner in which a mixture of coal gas and air burns with a non-luminous flame, it was supposed that the admixture of air supplying oxygen to the inner portion of the flame caused immediate and complete oxidation of the hydrocarbons without giving time for the liberation of carbon in the flame and consequent luminosity.

More modern researches, however, have proved this to be utterly wrong, the loss of luminosity being due to two causes:

1. The diluting action of the air introduced.

2. The fact that when a gas is so diluted it requires a far higher temperature to break up the hydrocarbons present than when the gas is undiluted; and, therefore, the temperature which serves to liberate carbon, and render the undiluted gas flame luminous, is totally insufficient to do so in the diluted gas, and in consequence the hydrocarbon burns to carbon dioxide and water, without any such liberation, and hence with a non-luminous flame.

The truth of this theory can be easily proved by the fact that diluting the gas with nitrogen, carbon dioxide or even steam, serves to render it non-luminous, and, therefore, more rapid oxidation has very little or nothing to do with it, while the non-luminous flame can again be rendered luminous, either by heating the mixture of air and gas just before combustion, or by heating the air with which the gas is diluted.

This being so, it is evident that in the non-luminous flame we have the same hydrocarbons present as in the luminous flame, and anything which will tend to break them up and liberate the carbon before the hydrocarbons are consumed should again make the flame luminous.

That heat will do this has been already shown, but it can be demonstrated in a still more striking way. It is well known that chlorine gas and bromine vapor will both support the combustion of a gas containing much hydrogen, but that the combustion is very different from that of the same gas burning in air, as the chlorine or bromine, having no affinity for the carbon, combines with the hydrogen only, and deposits the carbon in clouds of soot. In other words, at the temperature of flame chlorine will break up the hydrocarbons and liberate solid carbon. If now a small quantity of chlorine be led into the non-luminous Bunsen flame, it at once becomes luminous, proving conclusively that luminosity is due to solid particles of carbon liberated in the flame.

Again, Heumann points out that a small rod held in the luminous flame becomes rapidly covered on its lower side with a deposit of soot, *i. e.*, the soot is present in particles in the flame, and the uprush of the gas drives it against the rod, and deposits it there. If the soot were present in the flame, as Frankland supposes, in the state of vapor, and the rod merely acted by cooling and condensing it, then the soot should be deposited on all sides of the rod, while a still further proof is that if the soot existed as vapor in the flame, then if the rod were heated to a high temperature, no soot should be deposited on it, whereas the soot deposits on a heated surface just as well as on a cool one.

It has been objected to the solid particle theory that if it were true, then solid carbon particles introduced into a non-luminous flame should render it luminous, and make it look like an ordinary gas flame, whereas it simply gives rise to a cloud of sparks. But it must be remembered that the "nascent" carbon, as it is liberated from the decomposing hydrocarbons, is in the molecular condition, and has a very different degree of coarse-grainedness to any preparation of charcoal or lampblack we can make, and that although our finest particle is a mass which takes so long to burn that it leaves the flame only partly consumed, and is projected into the air as a spark, yet the molecular particles of carbon are consumed as soon as they are rendered incandescent, and a steady luminosity free from sparks results.

It is possible, however, to make the particles in a luminous flame roll themselves together, when they can be either deposited in a very coarse kind of soot or be seen as glowing sparks and particles in the mantle of the flame. This can be done when two luminous flames are allowed to rush against each other or against a heated surface. Heumann also shows that the luminous mantle of a flame is not altogether transparent, and that the thicker the flame layer and the greater the number of solid particles contained in it, the less transparent does it become. If a non-luminous hydrogen flame is charged with the vapor of chromyl dichloride (CrO_2Cl_2), chromic oxide is produced, and this flame, undoubtedly containing solid particles, is quite as transparent as the hydrocarbon flame; while, finally, those flames which undoubtedly owe their luminosity to the presence of finely divided solid matter produce characteristic shadows when viewed in sunlight; the only luminous flames which do not throw shadows being those which consist of glowing vapors and gases. Luminous gas flame, oil lamp flame, and candle flames produce strongly marked shadows in sunlight, and therefore contain finely divided solid matter, and that this can be nothing but carbon is evident from the fact that all other substances capable of remaining solid at the temperature of these flames are absent.

From these considerations it seems to me that Sir Humphry Davy's statement that "the intensity of the light of flames (such as candle, oil, or gas) depends principally upon the production and ignition of solid matter in combustion," is undoubtedly the true one, and we must also bear in mind that the degree of luminosity of a flame is affected by the constituents of the gas other than heavy hydrocarbons; some, like marsh gas, although ordinarily burning with an apparently non-luminous flame and separating no soot, yet add considerably to the luminosity at the temperature of the flame, while others like carbon monoxide reduce it.

This question, which I hope to discuss in the next lecture, has most important bearings upon the illuminating values of the newer forms of gaseous illuminants; and, finally, in considering the amount of light obtainable from a flame, we must not lose sight of the question of temperature, which will be best brought to your notice when speaking of the newer forms of burners employed in the combustion of coal gas.

The luminosity of a flame is increased by increase of density in the media in which it is burning, and decreased by rarefaction, facts made strikingly clear by Frankland's experiments, although noted as early as 1658 by Boyle. The effect was supposed by Frankland to be due to the alteration of the mobility of the oxygen molecules in the air with the alteration in density; this view, however, is contested by Wartha, who concludes that it is due to the effect of pressure on the dissociation point of the hydrocarbons burning in the flame, this taking place more rapidly under an increased pressure, and the carbon being therefore more quickly liberated. Be this as it may, the effect of pressure on luminous flames is very marked even under ordinary atmospheric pressure, the difference of an inch in the barometric column making 5 per cent. difference in the luminosity, *i. e.*, a burner giving 100 units of light with the barometer at 30 in. would only give 95 if it fell to 29, while a rise to 31 in. would mean an increase of the luminosity to 105 units.

II.

Having collected the known facts bearing upon the cause of luminosity of flames burning under ordinary atmospheric conditions, and having seen that such luminosity is governed by the separation of nascent carbon due to the decomposition by the heat of the flame of heavy hydrocarbons present in the gas, it is evident that anything which affects the quantity of hydrocarbons present, the ease with which they decompose or the temperature of the flame, must also affect the luminosity, while a great deal will also depend upon the characteristic properties of the portions of the gas which act as carriers of the illuminating compounds.

In the various analyses of illuminating gases, the heavy hydrocarbons are as a rule expressed as "illuminants," and used to be considered to consist mainly of ethylene, an idea which the researches of the last few years have shown to be totally erroneous. Besides ethylene there are undoubtedly present benzene, propylene, butylene, and acetylene, and also such members of the paraffin series as ethane, propane, and butane, while under certain circumstances crotonylene, terene, allylene, and others are present, so that the determination of the illuminants is by no means the simple process one would imagine it to be from the directions given in most text books on gas analysis.

The illuminants present in any given sample of coal gas depend upon (1) the kind of coal used, (2) the temperature at which the coal is distilled, and (3) the length of time during which the gas is in contact with the heated sides of the retort, and also the time during which it is in contact with the liquid products of the distillation.

1. The kind of coal used.

In an important paper read before the Society of Chemical Industry in January, 1885, Mr. G. E. Davis describes experiments on the hydrocarbons in ordinary and cannel gas, in which he passed large volumes of the gases through olive oil. This oil has the power of absorbing any hydrocarbon vapors of compounds liquid at ordinary temperatures, which are being borne along as vapor by the carrying power of the hydrogen present in the gas. He found that illuminating gas from 17 to 19 candle power was reduced to 8, and that on recovering the hydrocarbons from the absorbent, a very small fraction, not exceeding 2 per cent., had a boiling point below 80° C.; while with cannel gas, having an illuminating power of 27 candles, on passing through the olive oil the candle power fell to 19. The hydrocarbons, on being separated, proved to be very different, 29·9 per cent. boiling below 80° C.; while 12 per cent. had a boiling point below 23° C., and probably consisted of crotonylene.

2. The temperature at which the coal is distilled.

As the temperature is increased, the yield of gas from a given weight of coal also increases, but with the increase of volume there is a marked decrease in the illuminating value of the gas evolved. Mr. Lewis T. Wright, in a series of experiments (*Journal of the Chemical Society*, 1884, p. 99), found that when four portions of the same coal were distilled at temperatures ranging from a dull red heat to the highest temperature attainable in an iron retort, he got the following results as to yield and illuminating power:

Temperature.	Gas per ton.	Illuminating power.	Total candles per ton.
I. Dull red	8,250	20·5	33,950
II. Hotter	9,693	17·8	34,510
III. Hotter	10,821	16·7	36,140
IV. Bright orange	12,006	15·6	37,460

COMPOSITION OF THE GAS.

	I.	II.	IV.
Hydrogen	38·09	43·77	48·02
Marsh gas	42·72	34·50	30·70
Olefines	7·55	5·83	4·51
Carbon monoxide	8·72	12·50	13·96
Nitrogen	2·92	3·40	2·81

The gas analysis of No. III. was lost, but the illuminating power shows that it is intermediate in composition between II. and IV.

From this it will be seen that with the increase of temperature the hydrocarbons (the olefines and marsh gas series) gradually break up, depositing carbon in the crown of the retort, and liberating hydrogen, the percentage of which steadily increases with the rise of temperature.

This breaking down of the hydrocarbons does not proceed in any regular progression, bodies being built up as well as broken down during the action, the general tendency being, however, to form simple molecules until at last complete decomposition ensues, the higher members of the paraffin series being probably converted into paraffins and olefines of lower molecular weight. Butane, for instance, at a high temperature is resolved into ethane and ethylene, while at a still higher temperature ethylene will form ethane and acetylene, and still further break up into methane and carbon, the methane itself being at last broken up. Indeed the heavy hydrocarbons undergo such analytical and synthetical changes at a high temperature that, given any member of the series, you may have it resolved into carbon and hydrogen under one set of circumstances, while under others methane may become converted at high temperatures into naphthalene and acetylene, and it is this fact which gives such varying composition to the illuminants present in the gas.

3. The length of time during which the gas is in contact with the heated sides of the retort and with the liquid products of distillation.

When once evolved, the gas should not remain longer than necessary in the retort, as the sides being at a higher temperature than the charge, the hydrocarbons present become broken down in the way previously indicated, with deposition of carbon in the crown of the retort. If the gas remains in contact with the tarry products of distillation, the tar will absorb a considerable amount of the volatile hydrocarbon vapor and seriously impair the illuminating value of the gas, becoming itself much more liquid, so that the gas should be removed from the presence of tar before the latter has time to cool.

All analyses of coal gas have so far been founded on the assumption that the "illuminants," *i. e.*, the heavy hydrocarbons responsible for the illuminating power, could be absorbed by fuming sulphuric acid, chlorine, or bromine. This, however, is undoubtedly not the case. Mr. Wright has shown that when coal gas has been treated with fuming sulphuric acid, the residual gas still retains from 32 to 55 per cent. of its original luminosity, and although this may be to a certain extent due to the methane, which at high temperatures becomes slightly luminous, still it is certain that a considerable percentage is due to the higher members of the paraffin series not absorbed by the fuming sulphuric acid, and which the methods of analysis usually employed utterly fail to detect. Indeed, given a gas containing any member of the paraffin series other than methane, the analytical results are not only incorrect, but very misleading, as the percentages of hydrogen and methane present will be absolutely nullified by a very small quantity of the higher hydrocarbons.

In the analysis of an illuminating gas of the kind generally supplied up to a few months ago, the general process of the analysis consisted in taking a measured volume of the gas over mercury, and

1. Absorbing sulpureted hydrogen by manganese dioxide impregnated with phosphoric acid.

2. Absorbing carbon dioxide by potash.

3. Absorbing oxygen by alkaline pyrogallate.

4. Absorbing the "illuminants" with sulphur trioxide dissolved in Nordhausen sulphuric acid, and washing the remaining gas with potash to remove any sulphur dioxide from the acid used.

5. Absorbing carbon monoxide with acid cuprous chloride.

The residual gas was then looked upon as consisting of methane, hydrogen, and nitrogen, and was exploded with excess of oxygen over mercury. The volume of carbon dioxide formed was estimated by absorption with potash and gave the volume of methane, while the residual gas, after the removal of excess of hydrogen by potassic pyrogallate, was looked upon as nitrogen, and the hydrogen was obtained by difference. This method, as employed by Bunsen, gave results which were approximately correct, but inasmuch as the absorbents had to be introduced into the measuring eudiometer on various absorbent substances, and as it was also hampered by a mass of necessary corrections, the time taken by an analysis was enormous. The results also, when obtained, gave practically no insight into the composition of the gas, and this method, as well as the succeeding ones, was open to a grave objection which will be discussed later on. The first steps toward simplifying the process were made by Prof. MacLeod in his modification of the Frankland-Ward apparatus, and was still further improved upon by Mr. Thomas, but the apparatus still remained too ponderous and the process too long for technical analysis, where the operation must be performed in at most two hours, in order to be of use to the gas manager or experimentalist desirous of checking the actions going on in any process. The next step was the introduction of Stead's apparatus, in which mercury was used, and in which also very convenient arrangements were made for transferring the gas to the laboratory vessels and bringing them back to the measuring tube eudiometer, and, finally, accuracy has been still more sacrificed to speed in the Orset-Meucke and Hempsel's burette, which atones, as far as possible, for the errors introduced from the use of water instead of mercury, by the large volumes of gas which can be worked with at a time.

The processes instituted by Bunsen, and used with all forms of mercury apparatus, have several drawbacks, the chief one being that the residue left after absorption with cuprous chloride was looked upon as hydrogen, methane, and nitrogen, and that these were estimated by explosion with oxygen, and the volume of carbon dioxide formed was taken as representing the volume of methane.

Now all researches on the composition of coal gas point to the presence of ethane, and probably higher members of the marsh gas series, while in carbureted gases they are undoubtedly present to a far higher extent.

Ethane, propane, and butane have all been shown to be present in small quantities, and as ethane gives double its own volume of carbon dioxide, propane three times, and butane four times its volume, it is evident that exploding with oxygen, and taking the volume of carbon dioxide as representing marsh gas, will undoubtedly give too high results with an ordinary coal gas, while with a carbureted gas it will render the whole analysis useless. Moreover, the free oxygen is next absorbed and the remainder taken as nitrogen, while the volume of gas after absorption by cuprous chloride, less the marsh gas and nitrogen obtained as above, is taken as representing the hydrogen in the gas. The result being that the hydrogen is always far too low, not only because the volume of marsh gas is too high, but also because the residual nitrogen having to bear the brunt of all the errors of analysis throughout some seven or eight absorptions is also nearly always too high.

These palpable errors in the quantity of marsh gas and hydrogen also render worthless the calculation of the carbon and hydrogen density of the gas, on which great stress has been laid by previous observers, so that on the whole it is not to be wondered at that no relation has been discovered between the carbon and hydrogen density and the illuminating value of the coal gas.

With the more rapid methods of technical analysis, it is evident that no explosion over water and subsequent measurements of carbon dioxide could give satisfactory or even approximate results, as the pressure at the moment of explosion, and subsequent reduction of pressure, causes the water to effervesce like soda water, from the absorption and then liberation of the carbon dioxide; and as this washes other gases dissolved in the water out of it, and leaves an indefinite quantity of carbon dioxide in solution, any such process must be discarded.

These troubles have induced chemists to suggest several modifications in the process, some of which aim at doing away altogether with explosion. Some of these, like the process of burning H, but not methane, by passage over palladium asbestos, are of great value, while others are of not much practical value.

The last method proposed for the analysis of coal gas, without explosion, was published this year, and consisted of—

1. Absorbing the illuminants by strong alcohol.
2. Absorbing carbon dioxide by potash.
3. Absorbing oxygen by pyrogallate of potash.
4. Absorbing carbon monoxide by cuprous chloride.
5. Absorbing hydrogen by alkaline solution of permanganate of potash, and calling the residual gas methane and nitrogen. The objections to this process are that alcohol not only absorbs the illuminants, but also a very large percentage—say 50 per cent.—of the methane, with considerable rapidity, that after washing with water from the alcohol vapors it would be useless to expect an exact determination of carbon dioxide, as it has been mostly dissolved by the water, and finally that, as far as my experiments have at present gone, alkaline permanganate is not a reliable absorbent for hydrogen.

I am, at the present time, working at the various processes of gas analysis and checking mixtures of pure hydrocarbons, work I hope to have ready for publication early next year. But so far the general scheme of analysis which I am following, and which gives me the best and most instructive results, is as follows:

Two Stead's apparatus are taken and placed with the entrance tubes end to end, and are filled, the one with distilled water saturated with air, and the other with clean, pure mercury. The gas to be tested is collected in one of the Stead absorbing tubes over water, so as to be saturated, and is then transferred over mercury in the eudiometer tube of the apparatus, and is measured and passed into sodic hydrate, to absorb the small traces of carbon dioxide to be found in the highly purified London gas. (When present in only small traces, the amount of the carbon dioxide lost by water saturation cannot be detected.) After absorption of carbon dioxide the gas is run into the second apparatus, and the oxygen estimated by absorption with alkaline pyrogallate, which must be strong and fresh, containing about 25 grammes of pyrogallic acid dissolved in 50 grammes of sodic hydrate in 200 of water. (It is absolutely essential that the solution should be fresh, as, after keeping for some time, it will evolve a considerable amount of carbon monoxide.) After absorption with pyrogallate, the gas is run back into the eudiometer of the apparatus, and is measured over water. The heavy hydrocarbons have now to be estimated, and inasmuch as benzene is one of the most valuable illuminants in the coal gas, it would be of great value if any absorbent could be found which would separate the benzene and ethylene series, but, unfortunately, such does not, as far as we know, exist, the ordinary absorbents having the following drawbacks: (1) Nordhausen sulphuric acid, in which sulphuric trioxide has been dissolved until it will solidify on cooling, absorbs both ethylene and benzene, and, therefore, cannot be used to separate them. (2) Fuming nitric acid is a good absorbent for both series. (3) Bromine water, or a potassic bromide solution of bromine, acts more rapidly on ethylene than on benzene; but undoubtedly does absorb a considerable quantity of the latter if in contact with a mixture of the two. (4) None of the above affect the methane series in diffused daylight. The nearest approximate result is obtained by treating the gas first with strong bromine water, but not leaving it too long in contact with it, and then removing bromine vapor over sodic hydrate, the absorption being taken as ethylene series; while the benzene is then absorbed by fuming nitric acid, or saturated Nordhausen acid, acid fumes being removed in the sodic hydrate tube before measurement over water. It is then passed into an absorption tube, filled with a fresh solution of ammoniacal cuprous chloride, to absorb carbon monoxide. (This must not be used for more than six determinations of an ordinary coal gas containing say 3 to 6 per cent. of carbon monoxide, or three of a carbureted water gas, as after much carbon monoxide has been absorbed, the solution has a tendency to again give up small quantities of the gas.) The gas is now returned to the mercury eudiometer tube, and, after measurement, is passed into an absorption tube with paraffin oil previously heated, until everything which will distill at 100 deg. C. has gone off, which absorbs ethane, propane, and a good deal of methane. The residue is now washed and mixed with oxygen (which has itself been analyzed, so that the percentage of nitrogen and foreign gases in it are known), the mixture is exploded over mercury, and the carbon dioxide formed is estimated. The volume of carbon dioxide formed, plus the volume of gas absorbed by the paraffin oil, then gives the volume of gases in the methane series. A fresh portion of gas is now taken over mercury, and is exploded with excess of analyzed oxygen, the carbon dioxide is absorbed by sodic hydrate and the oxygen by pyrogallate, and the residue will be the nitrogen, the hydrogen being determined by difference.

It must, however, be clearly borne in mind that any such separation of the ethylene and benzene is not in any way accurate. The absorptions by bromine water and nitric acid, when added together, give the true quantity of olefines, while the volume absorbed by the paraffin oil added to the volume of carbon dioxide found during explosion gives accurately the volumes of gases in the methane series, but beyond this any subdivision of the constituents is purely approximate. In this way an analysis of South Metropolitan gas shows:

	Hydrogen		47·9	
Illuminants	Ethylene series	approx.	3·5	Total hydrocarbons. 45·6 per ct.
	Benzene "	approx.	0·9	
	Methane "	by paraffin.	7·9	
		" explos'n	33·3	
	Carbon monoxide		6·0	
	Carbon dioxide		0·0	
	Oxygen		0·5	
	Nitrogen		0·0	
			100·0	

In such an analysis no pretense is made that the exact percentage of the various illuminants is given, but the total of the illuminants is accurate, and their rough subdivision gives a far clearer insight into the characters of the gas than the more pretentious and more faulty analysis we have been in the habit of arguing upon.

It must be clearly borne in mind that I only put this scheme of analysis forward to meet the need now rapidly arising for a method which will show whether we are dealing with an ordinary coal gas enriched by cannel, a coal gas carbureted with either gasoline or oil gas, or with a coal gas enriched by highly carbureted water gas. In the first case the ethylene and benzene series will be found well represented, while the carbon monoxide is low. In the second, the amount of hydrocarbons in the methane series will have increased, and if oil gas has been used, a small increase in carbon monoxide may also be noticed, while the presence of carbureted water gas at once brings up the quantity of carbon monoxide, and the members of the methane series become the important illuminants. The illuminating value of the hydrocarbons present in the coal gas varies very greatly, the illuminating power increasing very rapidly with the number of carbon atoms in the molecule, and a rough idea of the value of the hydrocarbons in the various series may be obtained from the illuminating values of those experimented with by Frankland and Thorne, Knublauch, and others.

ILLUMINATING VALUE OF HYDROCARBONS PER FIVE CUBIC FEET OF VAPOR.

	Candles.
Methane	5·2
Ethane	35·7
Propane	56·7
Ethylene	70·0
Benzene	420·0
Toluene	741·7
Naphthalene	990·9

The two latter* being calculated from Knublauch's figures. From this it is seen that the illuminating value of benzene and the other hydrocarbons of that series is enormously more valuable than members of the methane series, and there is little doubt but that these bodies carried as vapors by the gas are the most important of the illuminants, their presence being amply proved by the fact that on compressing coal gas under a pressure of 14 atmospheres, *i. e.*, 14 by 15 lb. on the square inch, benzene, xylene, and other members of that series can be separated out as a liquid.

The action of the diluents present in coal gas upon its illuminating power has been determined by taking ethylene with an illuminating power of 68·5 candles as a representative of the hydrocarbons present in coal gas, and diluting with the various diluents present in coal gas. By this process the following results were obtained by Dr. Percy Frankland:

COMBUSTIBLE DILUENTS.

Diluent.	Percentage Ethylene.	Percentage Diluent.	Candle Power per 5 c. ft. per hour.
Hydrogen	77·55	22·45	54·58
	68·39	31·61	49·37
	53·58	46·42	38·21
	35·47	64·53	30·85
	26·08	73·92	22·84
	13·37	86·63	6·73
	10·00	90·00	0·00
Carbon monoxide	81·65	18·35	55·27
	67·75	32·25	47·73
	46·30	53·70	33·09
	37·94	62·06	26·52
	28·73	71·27	13·26
	23·89	76·11	6·56
	20·00	80·00	0·00
Methane	85·67	14·33	57·91
	69·09	30·91	47·88
	57·74	42·26	40·42
	35·90	64·10	33·17
	13·00	87·00	19·35
	7·87	92·13	17·59

These results show that, with the combustible diluents, hydrogen reduces the illuminating power least with large quantities of the hydrocarbons, but that methane is preferable when in excess, as with low percentages of the illuminant, especially when burnt at a high temperature, methane itself becomes a feeble illuminating agent.

This is due to the fact that, although, when the marsh gas or methane burns at ordinary temperatures, it is non-luminous, at a high temperature some of it is broken up into acetylene, which gives it distinct luminosity.

Carbon monoxide is the most injurious of the combustible illuminants, 80 per cent. mixed with ethylene rendering it non-luminous, a result which would require 90 per cent. of hydrogen.

The influence of incombustible diluents on the illuminating power of flames containing hydrocarbons has been also determined, with the following results:

NON-COMBUSTIBLE DILUENTS.

Diluent.	Percentage Ethylene.	Percentage Diluent.	Candle Power per 5 c. ft. of Gas.
Carbon dioxide	93·68	6·32	55·52
	90·59	9·41	51·81
	89·03	10·97	49·98
	81·73	18·27	42·81
	70·75	29·25	33·23
	64·14	35·85	26·52
	52·94	47·06	14·72
	45·61	54·39	7·49
	40·00	60·00	0·00
Nitrogen	84·69	15·31	51·96
	71·12	28·88	39·58
	59·93	40·07	29·64
	47·08	59·92	20·81
	36·24	63·76	11·82
	28·81	71·19	7·20
Oxygen	82·57	17·43	70·93
	80·67	19·33	72·53
	75·51	24·49	74·19
	68·50	31·50	71·17
	60·69	39·31	Explosion
Air	79·68	20·32	54·45
	67·15	32·85	45·84
	55·92	44·08	37·16
	42·69	57·31	26·78
	33·91	66·09	16·22
	22·31	77·69	0·61
	13·31	86·69	Explosion

While moisture when present to the extent of 2 per cent. (the proportion present in coal gas saturated at 20 deg. C. and 760 mm.) in ethylene reduces the illuminating power 3·6 per cent., or in coal gas 3·8 per cent.

Of the inert or non-combustible diluents, therefore, carbon dioxide is the most injurious, and atmospheric air is the least harmful.

Wurtz has also determined the loss of light incidental on addition of air to coal gas, and gives the following results:

Added Air.	Percentage Loss of Light.
3·00	15·69
4·96	23·88
11·71	41·46
16·18	57·53
25·00	84·00

The addition of oxygen to gases rich in hydrocarbons causes an increase in the illuminating power, up to a certain point. The temperature of the flame is increased by burning up the hydrogen of the hydrocarbons, and rendering the carbon incandescent without diluting the flame with nitrogen to the extent which would have been necessary had air been used for the purpose.

The effect of such gases as hydrogen, marsh gas, and carbon monoxide is simply to dilute the flame, and, by separating the molecules of the hydrocarbons, to make them more difficult to decompose; while such bodies as the carbon dioxide, nitrogen, air and water vapor not only dilute but also cool the flame, as they do not add to the heat by any action of their own, and have to be heated up to the same temperature as the flame itself.

Rosette determined the temperature of a gas flame diluted with air, nitrogen, and carbon dioxide respectively, and found that it was least with the carbon dioxide and highest with air, a result which agrees with Dr. Frankland's determination of illuminating power. His figures are:

Volumes Taken.		Temperature.		
Gas.	Diluent.	Air.	Nitrogen.	Carb'n Dioxide
Vol.	Vol.	Deg. C.	Deg. C.	Deg. C.
1	1	....	1,180	1,100
1	2	1,260	1,150	880
1	3	1,116	1,040	780

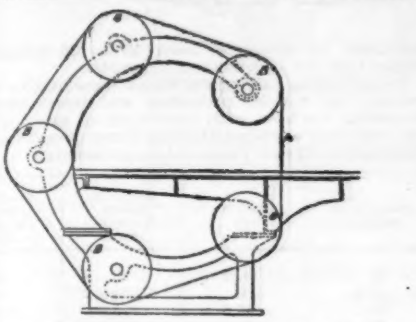
(*To be continued.*)

BAND KNIFE FOR CUTTING FABRICS.

IN the using of band saw machines for the cutting of cloth and fabrics of various descriptions, many complaints have been made of, and much loss of time experienced in, the breaking of the saws. These breakages often occur through the quality of the metal of which the saw is made being inferior, but a leading cause, and one that entails the greatest number of difficulties, is the want of uniform or regular tension upon the knife or saw throughout its whole length. It is well known that, although the metal may be of the

very best quality procurable, an irregular tension speedily weakens this knife or saw, and, even if no breakage result, the running of the knife is so erratic that the cutting of the cloth in a clean and regular manner is a matter of no little difficulty, and, at the same time, the working of the machine necessitates a greater amount of power than is really requisite when the knife tension is correct. This latter evil may not seem so great if calculated upon a single machine, but, in establishments where they are used by the score, the loss of power proves an item sensibly felt in the long run.

To overcome these difficulties, Mr. R. H. Harry, of the firm of Aublet, Harry & Co., engineers, Curtain Road, London, has invented an improvement upon the existing mechanisms that ought to be welcomed by all users. The end in view is attained by mounting, on a suitable frame, three or more wheels, equidistant from each other, over which the knife or saw revolves, as shown in the accompanying drawing of a five-wheeled machine. B represents five wheels of equal



BAND KNIFE FOR CUTTING FABRICS.

diameter, the centers of which form a circle divided into five equal parts. A is an endless knife or saw, which passes over the five wheels. By the means employed, an equal and uniform tension is insured, giving the advantages required by users.

CONDENSATION OF CARBON PARTICLES IN SMOKE.

By ROBERT IRVINE, F.C.S., F.R.S. Ed.

IN the Society's *Journal*, May 31, 1889, there is a short note (communicated by me) on the condensation of carbon particles in smoke, and as it represents the initial stage of the investigation, I make it the preface to the paper I am to communicate this evening on the same subject.

"In the manufacture of lamp black, hydrocarbons are burned in an atmosphere with a limited supply of oxygen, the resulting dense black smoke is conducted into large chambers, where, on account of the extremely sluggish draught, it is allowed to roll about until the particles, by attraction between themselves, gradually coalesce into masses, which after a lengthy period fall on the floor in the form of soot. This process is exceedingly slow, and the product obtained, from even an enormous condensing space, is comparatively very small. Consequently this manufacture is one carried on on a limited scale, considering the magnitude of the plant required.

"I erected a glass structure 5 ft. × 4 ft. × 4 ft., in which were fixed two malleable iron plates, provided with a great number of points—these facing each other, the plates being separated by a distance of from two to three feet, and all the conducting surfaces, except these points, being carefully insulated with shellac varnish. This chamber was filled with smoke produced by burning pitch oil, which retained its opacity for at least two hours, so much so that on then looking through the chamber, a bright light placed on the other side was totally obscured by the vapor. The chamber was now refilled with smoke, and the whole atmosphere therein was to a greater or less degree electrified by coupling the conductors, which were connected to the plates with a small dynamo. The effect immediately produced was exceedingly striking, the minute particles of carbon at once separated from the opaque smoke, and were attracted to or driven from the points of the plates, congregating together in a most extraordinary manner, and in the space of two or three minutes the atmosphere in the glass chamber was almost entirely cleared of smoke. The prohibitory cost of electricity has however prevented the application of this process on a large scale, for the present at least."

This led me to infer that the condensation of the minute particles of carbon in smoke into concrete masses could be effected by simpler and cheaper means. I carried out a series of experiments by which smoke was rapidly agitated by mechanical means. The results were practically the same as those obtained by electric disturbance.

Before proceeding to explain in detail these experiments, I wish to direct your attention to some of the properties of the products obtained when fuel is burned, more especially that known as coal.

When a microscopic slide is passed quickly over a smoky flame, a very thin, semi-transparent film is left on the glass, which, when examined under a powerful microscope, presents the appearance of numerous particles of amorphous carbon, in a very finely divided condition, each particle surrounded by an areola, or coating of oily matter.

Here we have an explanation of two things: First, why a black fog may be and will remain persistently a fog while rain is falling; each particle of carbon being, so to speak, surrounded by a waterproof coating and hence repelling moisture. Second, when the particles composing such a smoke fog are agitated, either by currents caused by changes of temperature or by a vertical down draught of air, this oleaginous coating causes the finely divided carbon particles to cohere, forming masses which the air cannot long support in suspension, and their condensation into greasy black smuts ensues, often with startling rapidity, and the fog clears.

If commercial lamp black, or soot, which is the product of imperfectly burnt coal, is strongly heated, a large amount of empyreumatic matter is given off, which condenses on cooling into a brown greasy mass, consisting of crysene, pyrene, capnomar, etc., which causes ordinary lamp black to cohere like damp snow when pressed, while after calcination (during which it has been deprived of the oily or greasy matter) it loses this property.

If we examine the smoke from a newly made (or mended) fire, we find at first only light blue and yellow brown colored vapors given off (consisting principally of the solid and liquid hydrocarbons before referred to), these passing into the atmosphere, with which, if I may use the term, they "emulsify." The first stage is followed by the combustion of these products, which, as the coal becomes heated, are resolved into gases, which burn with a smoky flame. It is at this stage, owing to the imperfect combustion of these gases, that we have finely divided particles of carbon formed, and the black smoke so produced is added to the grease-laden air of the first stage, and so long as the atmosphere into which these products are poured remains cold, damp, and still, what is known as a black or brown fog results.

In the last or perfect combustion stage, after all the volatile or bituminous matter has been driven off as gas and burned (represented by a red, glowing, smokeless mass of burning coke), we have nothing but carbonic acid and water and some sulphurous compounds given off, which also pass into the air, but black fog cannot result from such products.

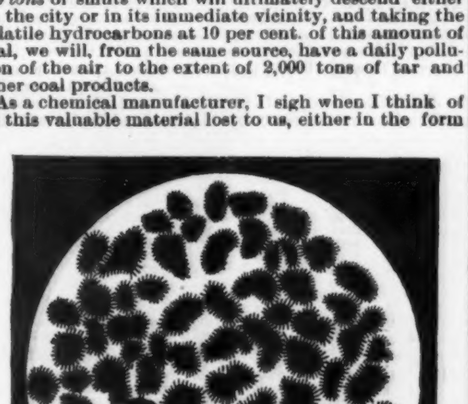
Taking the total products from a coal fire, consisting of permanent gases, carbon, greasy hydrocarbons, and water all together, the percentage amount of the carbon is very small, yet so great is its power of obstructing the light, that the amount present in the blackest fogs of our large towns is represented by the insignificant quantity of blacks or smuts which fall to the earth when the fog clears. This is estimated at 3 per cent. of the whole smoke.

We are aware that dense fogs disappear in many cases without apparent atmospheric changes or wind storms to drive away the smoke. This may be as already stated due to electrical disturbances or convection air currents, or to sudden rise of temperature in the atmosphere in which the smoke matter is suspended. In any and all cases, however, the effect is the same, viz., the agglomeration of the minute carbon particles into masses too heavy for the atmosphere to retain them in suspension; this agglomeration being due to the presence of hydrocarbons, which we have found to accompany or clothe each carbon atom in the smoke, and which causes it to deposit upon and defile buildings, trees, flowers, and other objects of beauty in and around our cities.

In a smoky town, when a breeze prevails, the smoke, in its horizontal passage through the air, gradually parts with its greasy coated carbon to anything which impedes its progress, so that only a few miles away it loses its dolorous aspect, and assumes the soft, dreamy haze so dear to the soul of the painter, but which, after all, is only an air emulsion of finely attenuated particles of grease.

This smoke and fog question, from an economic point of view, presents interesting features. The Hon. Rollo Russell, in a lecture delivered under the auspices of the National Smoke Abatement Institution, states that 20,000 tons of coal are consumed per diem in London alone. We will therefore, taking the solid carbon produced at only 3 per cent. of the coal burned, have 600 *tons* of smuts which will ultimately descend either on the city or in its immediate vicinity, and taking the volatile hydrocarbons at 10 per cent. of this amount of coal, we will, from the same source, have a daily pollution of the air to the extent of 2,000 tons of tar and other coal products.

As a chemical manufacturer, I sigh when I think of all this valuable material lost to us, either in the form



MICROSCOPIC VIEW OF SMOKE PARTICLES SHOWING "AREOLA" OF HYDROCARBONS SURROUNDING THEM.

of wasted heat producers or valuable chemical products in the shape of *aniline colors, ammonia, burning oils, paraffin wax, printing ink, etc.*, which, divorced from their natural channels, are floating about in the atmosphere, veiling the sweet sunlight and choking the lungs of both animal and vegetable life.

Of course, if we could overcome our sentimental desire for the cheerful though smoky blaze of the coal fire, and burn carbonized coal in our grates, these solid, liquid, and gaseous hydrocarbons would be saved and made profitable use of. In this case our chimneys might become ornaments to our houses, while the products of combustion would pass from thence as colorless gases.

But if we will insist on burning green coal, it is possible for us to do so and have the enjoyment of the blazing fire by constructing our house grates so that the green coal may be introduced at the bottom (as is now successfully accomplished in some forms of steam boiler furnaces), by which means the hydrocarbons given off from the heated coal are made to pass (with a regulated supply of air) up through the mass of incandescent coke, which by this means would occupy the upper portion of the fire instead of the lower.

Many attempts have been made to introduce such a perfect combustion grate, but the usual condition of the atmosphere of our large towns proves that, as yet, either a scientifically constructed grate, or one requiring extra care or involving extra attention on the part of the class who minister to the "smoke fiend," is far from general adoption.

In the coke and iron industries much has been done in the direction of utilizing the gaseous and liquid products obtained from carbonized or partially coked coal, and processes are in general use by which these instead of being wasted are profitably made use of.

Efforts have been and are being made to introduce such carbonized coal (or coke) into use for household firing, and experience has proved its use to be twice as economical as ordinary coal, while it is impossible to produce smoke from it. But sentimental prejudices prevail over all such considerations as health, beauty, and what is more wonderful, money. Nor will there be an end of the allied sins of waste and dirt which we so strongly cling to (and which in this connection Russell, in his pamphlet before referred to, estimates costs the city of London alone nearly six million of money sterling) until the law compels us to burn smokeless fuel either in the form of coke or gas.

Consequently upon the failure (from a money point of view) of the condensation of smoke particles by means of electric currents, as already explained, I tried to obtain the same results as were then observed, by mechanical agitation of smoke, and I constructed a flue or chamber, partly horizontal and partly perpendicular, through which dense smoke, obtained by burning naphtha at the one end, was passed. In this chamber (which was a box about 20 ft. long and 1 ft. wide) were placed two sets of fanners, which were made to revolve near the point where the smoke entered, so that it might be driven about in the confined space, my idea being that under these circumstances the particles of oily-coated carbon would by their impact coalesce into large smuts and condense *in situ*.

On starting these experiments the smoke was allowed to pass through the apparatus undisturbed, and at the exit end of the flue a loose plug of white cotton wool was placed, so that the smoke had to pass through it without its exit being impeded. Two minutes after this plug was applied the amount of carbon condensed among the fibers had blackened it completely. A second plug replaced the first, which was again blackened in the same space of time. The fanners in the box were now set in motion, and what followed was observed through spy holes in the box and flue, both behind and in front of where the fanners were at work. Before agitation there was the dense brown black homogeneous cloud which the undisturbed smoke presented. After agitation we had an effect very similar to the breaking up of a mist scene among the hills; large, veil-like black streaks taking fantastic shapes, and a continuous shower of large particles of carbon falling within the flue or chamber, a few feet from the point where the agitation of the smoke had taken place.

At this stage another plug of white cotton wool was placed at the exit of the flue; after two minutes this presented only a gray appearance. A second and a third plug exposed for the same time to the process showed less and less coloration, while the plug applied at the end of eight minutes showed hardly any stain, showing that most of the carbon particles in the smoke had been condensed. The same end can be arrived at by employing air jets so as to throw the smoke into rapid circulation. Of course the production of smoke was continuous during the experiments.

I have endeavored to repeat this experiment with smoke free from empyreumatic products, but the difficulty is to get smoke in such a condition. When gas is used for the production of carbon in the shape of fine lamp black, the smoke does not contain empyreumatic matter in any large proportion, but of course a large quantity of water vapor accompanies the carbon particles; and as the heated gases and water become cold, each particle of carbon is surrounded by condensed water which acts in the same manner as already described, in causing the particles to coalesce into large masses.

We are all familiar with the result of introducing a cold body into a gas flame. For instance, if a white plate is placed over a gas jet, we have at once deposition of carbon on the cold substance, which will not take place if the plate is heated to the same temperature as the flame. Advantage is taken of this fact in preparing a very fine variety of lamp black. And in America, where gas is given off in large quantity from the oil wells, a large trade has sprung up for the manufacture of what is called gas black.

Simultaneously with my observations on this smoke cure question, Mr. Elliott, of Queen Street, Cheapside, has introduced a means of smoke condensation, using an apparatus which virtually washes the smoke with water. I take the following descriptive account from a London paper:

"Mr. Elliott's apparatus virtually washes the smoke and converts it into innocuous steam, and turns the deleterious parts into lamp black and other coloring material. It can be attached to any chimney or works without interfering with the ordinary operations. The process is simple. The smoke is drawn from the flue by a fan with a closed chamber in which a rapidly revolving paddle wheel acts like a washing machine. The black thick smoke which enters emerges as colorless steam, which leaves no smell on a cambric handkerchief. The transformation is complete."

Such appliances as Mr. Elliott's washer, and agitating smoke in chambers, may be adopted in factories, when the smoke may easily be deprived of its carbon and hydrocarbons (and even the carbonic and sulphurous acids may thus be profitably utilized). That is to say, there is now no difficulty in preventing the emission of colored smoke from any factory chimney. Indeed, were the law to insist upon this being done, coal users would in the end find it to be to their profit. This remark applies equally to the largest factories and to the ordinary bakery. Perhaps then this is enough for the fulfillment of our duty as representing the Society of Chemical Industry. As yet we have been wholly unable to deal with the domestic smoke nuisance, which is almost as serious a problem to cope with as that of domestic drainage.

I need not further urge the immense importance of some means by which the enormous waste of valuable material may be prevented. Macauley, in a lecture delivered at Liverpool in February 1888, estimates the amount of coal wasted in this country per annum at 45,000,000 tons, costing 15,750,000*l.* at the pit mouth. We have seen in the experiments I made when smoke was agitated in a confined space, that it could be deprived of its carbon. The same thing can, of course, be effected by filtering the smoke through a porous material, or washing with water, but the adoption of any such plans as these would necessitate the entire reconstruction of our dwelling houses, and is consequently not to be thought of, even if it could be practically carried out. The only real source open to us seems to be in the use of a smokeless fuel in our domestic fire grates, or a grate which will prove in every respect a successful smoke consumer where coal is used.

Did time permit, I would lay before you statistics as to the additional sum in money which would be saved, added to what at present is lost (in consuming bituminous coal) by adopting such a fuel or grate, and in addition an appalling catalogue of death caused to animals and plants, which would be avoided.—*Jour. Soc. Chem. Industry.*

[Continued from SUPPLEMENT, No. 791, page 12643.]

THE POWER OF WATER, OR HYDRAULICS SIMPLIFIED.

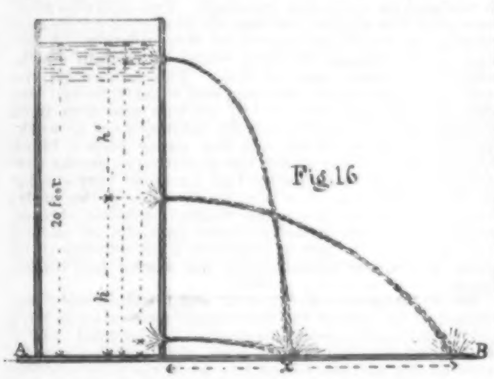
By G. D. HISCOX.

JETS AND FIRE NOZZLES.

THE velocity of a jet at the orifice is the same at all angles from horizontal to vertical, and where the flow behind the orifice is unobstructed by friction, is equal to a coefficient for the form of the aperture multiplied by the square root of the product of twice gravity multiplied by the height in feet, for which the formula is

$$C. \sqrt{2g \times h} = \text{velocity in feet per second.}$$

The greatest range of a horizontal jet on the floor line of a tank is when the orifice is placed in the middle of the water head, as shown in Fig. 16, while jets from



equal distances from the water head and floor line will meet at the floor line, as shown in the cut.

The curved form of these jets is that of a section of a parabola from its axis, which corresponds with the front line of the tank.

Using the terms as expressed in Fig. 16, for the distance that a jet will touch the horizon of the bottom of the tank, the coefficient of the velocity multiplied by twice the square root of the pressure head (h') multiplied by the height of the center of the orifice above the floor (A B), equals the distance from the line of the tank that the jet will strike the floor—or, using the best form of orifice,

$$0·93 \sqrt{h' \times h} \times 2 = x,$$

the distance as in Fig. 16.

For example with h = 10 ft., h' = 10, then

$$\sqrt{10 \times 10} = 10 \times 2 \times 0·93 = 18·6 \text{ feet,}$$

at which point the jet touches the floor line at B.

In the same way, using the above formula, the jet from both the top and bottom orifice will touch the floor line at eight feet from the front of the tank.

The quantity of water discharged by these jets will be

$$\text{coefficient} \times \frac{\text{area in square inches}}{144} \times \sqrt{2g \times h'} = \text{vol-}$$

ume in cubic feet per second: as

$$\sqrt{2g} = 8·02$$

the square root of the head in feet from the center of the orifice to the surface of the water may be used × by 8·02 for facilitating computation.

For example, taking the middle orifice in Fig. 16 at one inch in diameter, then the equation will be with the best form of orifice, and h' = 10 feet,

$$0·93 \times \frac{1'' \times 0·7854}{144} \times 8·02 \times \sqrt{10} = 0·138 \text{ of a cubic foot.}$$

per second.

Let it be here understood that static height and pressure by gauge in pipes, tanks and stand pipes are convertible terms, so that, where gauge pressure is expressed in pounds per square inch, it should be multiplied by 2·3093 for its equivalent height of head in feet, and when head in feet is expressed, it should be multiplied by 0·433 for pressure in pounds per square inch. For vertical jets or fountains the coefficient of velocity may vary for various forms of orifice, as shown in a former chapter, from 0·62 to 0·93 per cent. of the theoretical effect.

Taking the best form of nozzle, the formula for velocity becomes

$$0·93 \sqrt{2g \times h} = \text{velocity in feet per second,}$$

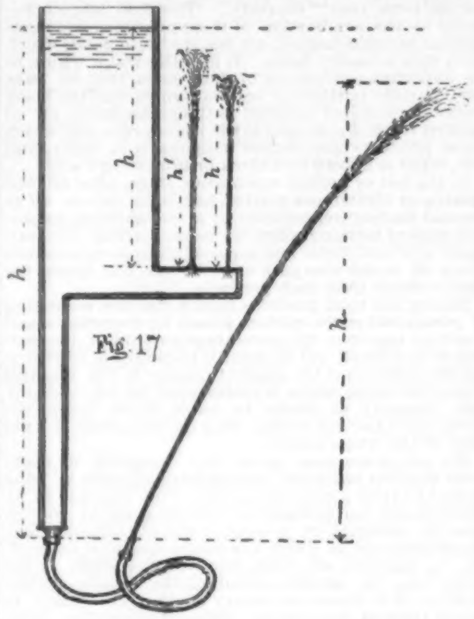
h being the height or head in feet of the source of supply, and not allowing for friction in intermediate pipes.

The height of the jet may be computed from the formula

$$\frac{V^2}{2g} = h'$$

or the square of the velocity divided by twice gravity equals the height of the jet.

For example, as illustrated in Fig. 17, with a head, h,



of 64 feet and a nozzle of best form, the computation becomes

$$0·93 \times \sqrt{64·33 \times 64}$$

the last terms of which may be multiplied together and the square root taken, or the square root of each member taken and multiplied, which reduced = 0·93 × 8·02 × 8 = 59·66, the velocity of the jet at the nozzle in feet per second, and

$$\frac{59·66^2}{64·33} = 55·32 \text{ feet,}$$

the height of the jet from a head of 64 feet.

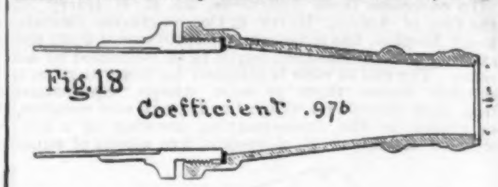
This does not include the friction in the reservoir or pipes leading to the nozzle or orifice. By using the coefficients for various forms of nozzle, the height of the vertical jet will be found to vary from 97 per cent. to 62 per cent. of the whole height, or, if the jet is taken from water mains, the gauge pressure multiplied by 2·3093 will represent the hydrostatic height to be used in the formulas.

The retardation by friction of the atmosphere affects height as given by the formulas to a considerable degree, small jets and any jets under high pressure being most retarded by air friction, as shown further on in the table of actual heights from Freeman's experiments.

The form of nozzle for fire streams has been the subject of experiment for many years, and has finally, in an exhaustive trial by John R. Freeman, C.E., resulted in a form probably the most perfect yet attained, having a coefficient of 0·976 for a 1⅛ inch nozzle, and a trifle greater coefficient with a ⅞ inch and ¾ inch nozzle of the same form on the same plug pipe, the advantage of the smaller stream being due to the less velocity friction between the pressure gauge at the foot of the butt and the nozzle.

This form is shown in its exact proportions in Fig. 18.

The loss of pressure in standard fire hose of 2½ inch diameter with a fairly smooth inner surface is, in ex-



periments by Freeman, from 13 to 14 pounds per square inch for each 100 feet in length.

The following table gives the extreme height of fire streams for various pressures, and water heads, as gauged at the butt, with best form of fire nozzles of two sizes, the intermediate sizes being proportional to their areas. (From Freeman's experiments.)

Pressure lbs. per sq. in.	Head in feet.	Height of stream, ¾ nozzle, Feet.	Height of stream, 1⅛ nozzle, Feet.
25	57·7	49	51
43·3	100	83·5	88
50	115·5	92·3	101·2
70	161·6	113·5	131·8
86·6	200	127	150·7
100	230·9	133·2	158·9

The loss of pressure or water head by friction in long hose is very serious, so that to maintain a ⅞ inch nozzle jet of 100 feet in height, which would require about 60 pounds pressure if thrown from the engine, would require 65 lb. with 50 feet of rubber-lined hose; 69 lb. with 100 feet; 75 lb. with 200 feet; 89 lb. with 400 feet; and 116 lb. with 800 feet.

With a limited pump pressure the height of the stream would fall in proportion with the increase in length of hose. For standard 2½ inch hose the difference in required pressure for a given height is considerably greater for nozzles above ⅞ in. diameter and less for those under ⅞ inch diameter than the differences above stated, the experiments showing that for 70 lb. pressure with 1⅛ in. nozzle and 50 feet best rubber-lined hose an effective fire stream of 81 feet in height could be attained, while with 250 feet of hose it was found to be only 61 feet, and with 500 feet of hose a height of only 46 feet could be attained.

The following table will be found very convenient for reference as to the theoretical velocity, discharge, and horse power of nozzles of various sizes from 1 in. to 4 in., and for various heads from 1 foot to 1,000 feet.

VELOCITY, DISCHARGE, AND HORSE POWER OF NOZZLES.

Head in Feet.	Velocity per Second in Feet.	Diameters of Nozzles. 1 inch.		1¼ inches.		2 inches.		2½ inches.		3 inches.		3½ inches.		4 inches.	
		Cu. ft.	H. P.	Cu. ft.	H. P.	Cu. ft.	H. P.	Cu. ft.	H. P.	Cu. ft.	H. P.	Cu. ft.	H. P.	Cu. ft.	H. P.
1	8·02	0·041	0·004	0·093	0·010	0·164	0·018	0·255	0·029	0·372	0·040	0·50	0·056	0·656	0·072
1½	9·82	0·050	0·006	0·111	0·019	0·200	0·034	0·312	0·053	0·444	0·076	0·61	0·105	0·800	0·136
2	11·35	0·058	0·013	0·130	0·028	0·232	0·052	0·360	0·082	0·520	0·116	0·70	0·160	0·928	0·208
2½	12·68	0·064	0·018	0·145	0·041	0·256	0·072	0·402	0·114	0·589	0·164	0·79	0·224	1·02	0·288
3	13·90	0·069	0·024	0·159	0·054	0·284	0·096	0·440	0·150	0·636	0·216	0·86	0·295	1·14	0·384
3½	15·01	0·076	0·030	0·171	0·066	0·304	0·120	0·475	0·189	0·684	0·272	0·94	0·370	1·22	0·480
4	16·05	0·081	0·037	0·183	0·083	0·324	0·148	0·507	0·231	0·742	0·332	1·02	0·452	1·30	0·592
4½	17·02	0·086	0·044	0·194	0·099	0·344	0·176	0·540	0·275	0·776	0·396	1·06	0·540	1·38	0·704
5	17·95	0·091	0·051	0·205	0·113	0·364	0·204	0·567	0·315	0·820	0·452	1·11	0·600	1·46	0·816
6	19·66	0·100	0·068	0·224	0·153	0·400	0·272	0·622	0·425	0·896	0·612	1·22	0·833	1·60	1·09
7	21·23	0·108	0·086	0·242	0·193	0·432	0·344	0·672	0·535	0·968	0·772	1·32	1·05	1·73	1·38
8	22·70	0·116	0·104	0·260	0·232	0·464	0·416	0·720	0·656	1·04	0·928	1·40	1·28	1·85	1·66
10	25·38	0·129	0·146	0·290	0·329	0·516	0·584	0·805	0·915	1·16	1·32	1·57	1·79	2·16	2·34
12½	28·37	0·144	0·204	0·324	0·460	0·576	0·816	0·897	1·28	1·30	1·84	1·76	2·50	2·30	3·46
15	31·08	0·158	0·269	0·355	0·505	0·632	1·08	0·985	1·68	1·42	2·42	1·93	3·29	2·53	4·32
17½	33·57	0·170	0·340	0·383	0·782	0·680	1·36	1·06	2·11	1·53	3·13	2·08	4·20	2·72	5·44
20	35·89	0·182	0·414	0·410	0·981	0·728	1·66	1·14	2·58	1·63	3·72	2·23	5·07	2·91	6·64
22½	38·07	0·193	0·494	0·435	1·11	0·772	1·98	1·21	3·08	1·74	4·44	2·36	6·05	3·09	7·92
25	40·13	0·204	0·578	0·458	1·30	0·816	2·31	1·27	3·61	1·83	5·20	2·54	7·08	3·26	9·24
27½	42·08	0·213	0·667	0·480	1·50	0·852	2·67	1·33	4·17	1·92	6·00	2·61	8·17	3·41	10·68
30	43·95	0·228	0·760	0·513	1·71	0·912	3·04	1·42	4·75	2·05	6·84	2·70	9·31	3·65	12·16
32½	45·75	0·232	0·857	0·522	1·93	0·928	3·43	1·45	5·35	2·09	7·72	2·84	10·50	3·71	13·72
35	47·47	0·241	0·968	0·542	2·15	0·964	3·83	1·51	5·98	2·17	8·60	2·95	11·71	3·86	15·32
40	50·75	0·257	1·17	0·579	2·63	1·03	4·68	1·61	7·31	2·32	10·52	3·15	14·33	4·12	18·72
45	53·83	0·273	1·40	0·614	3·14	1·09	5·60	1·71	8·23	2·46	12·56	3·34	17·10	4·36	22·40
50	56·75	0·288	1·64	0·648	3·66	1·15	6·56	1·79	10·2	2·59	14·72	3·52	20·03	4·60	26·24
60	62·16	0·315	2·15	0·700	4·84	1·26	8·60	1·97	13·4	2·84	19·36	3·86	26·32	5·04	34·40
70	67·14	0·341	2·71	0·766	6·10	1·36	10·8	2·13	16·9	3·06	24·40	4·17	33·17	5·42	43·36
80	71·78	0·364	3·31	0·819	7·45	1·46	13·2	2·27	20·6	3·28	29·80	4·46	40·55	5·84	52·96
90	76·13	0·386	3·95	0·864	8·88	1·54	15·8	2·44	24·6	3·46	35·52	4·73	48·37	6·16	63·20
100	80·25	0·407	4·63	0·916	10·4	1·63	18·5	2·54	28·9	3·66	41·64	4·98	56·67	6·52	74·08
125	89·72	0·455	6·47	1·03	14·1	1·82	25·8	2·84	40·4	4·08	58·20	5·57	79·20	7·28	103·5
150	98·28	0·499	8·60	1·12	19·1	2·00	34·0	3·11	53·1	4·48	76·48	6·10	104·1	8·00	136·0
175	106·1	0·539	10·7	1·21	24·0	2·16	42·8	3·36	66·8	4·84	96·28	6·60	131·5	8·04	171·2
200	113·5	0·576	13·1	1·29	29·4	2·30	52·4	3·59	81·7	5·10	117·7	7·06	160·2	9·20	219·6
250	127·1	0·644	18·3	1·45	41·1	2·58	73·2	4·02	114·0	5·87	164·5	7·88	223·9	10·3	292·8
300	139·0	0·705	24·0	1·59	54·0	2·82	96·9	4·40	150·0	6·36	216·3	8·63	294·3	11·2	384·0
350	150·1	0·762	30·3	1·71	68·1	3·05	121·0	4·76	189·0	6·84	272·6	9·33	371·2	12·2	484·8
400	160·5	0·814	37·0	1·83	83·2	3·26	148·0	5·09	231·0	7·30	323·0	9·97	453·2	13·0	592·0
450	170·2	0·864	44·2	1·94	99·3	3·46	176·0	5·40	276·0	7·76	407·4	10·5	541·0	13·8	707·0
500	179·4	0·910	51·7	2·05	116·0	3·64	206·0	5·69	323·0	8·20	466·0	11·1	627·0	14·5	827·2
550	188·2	0·955	59·7	2·10	134·0	3·82	238·0	5·96	372·0	8·40	536·8	11·6	731·0	15·2	955·2
600	196·6	0·999	68·0	2·23	152·0	3·99	272·0	6·23	475·0	8·92	611·0	12·2	832·7	16·9	1088·0
700	212·3	1·08	85·7	2·46	192·0	4·36	342·0	6·79	595·0	9·84	771·2	13·3	1051·0	17·4	1371·0
800	226·9	1·15	104·7	2·58	235·0	4·60	418·0	7·19	654·0	10·3	942·0	14·1	1282·0	18·4	1675·0
900	240·7	1·22	124·9	2·75	281·0	4·88	490·0	7·63	780·0	11·0	1124·0	14·9	1530·0	19·5	1998·0
1000	253·8	1·29	146·2	2·89	329·0	5·16	584·0	8·04	914·0	11·5	1316·0	15·7	1791·0	20·6	2339·0

The first column represents the height or head of water, the second column the theoretical velocity through nozzles of good form, without deduction for friction in pipes or flumes leading to the nozzles. The first column under the size of nozzle is the flow in cubic feet per second, the second that of the theoretical horse power, no allowance for the coefficient for water wheels being made, which amounts to from 60 to 86 per cent. of the power here given.

(*To be continued.*)

ORIGIN OF THE STEAM ENGINE AND OF THE UTILIZATION OF SOLAR HEAT.

MR. LOREDAN LARCHEY recently published in these pages the story of Anthemius, who in times of old made an application of the expansive force of steam. As the author supposes, the narrative that he recalls was known to those who have occupied themselves specially with the history of steam. Heron, of Alexandria, in addition to the eolipyle, devised several apparatus based upon the vaporization of water that may be found described in the *Origines de la Science*, which forms part of the *Bibliotheque de la Nature*.

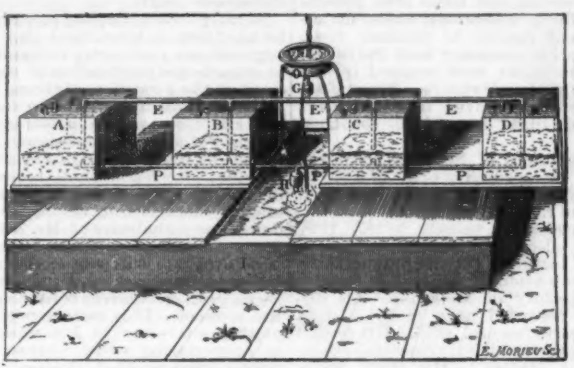


FIG. 1.—DE CAUS APPARATUS FOR UTILIZING SOLAR HEAT.

At the epoch of the Renaissance, a learned Italian, the celebrated Porta, likewise, in imitation of the Greek engineer, conceived the idea of utilizing the force of steam. The following is Jean Escrivano's account of the conception of the Porta apparatus, as found in an Italian edition (*I tre libri spiritali*, Naples 1608) that he gave of the Book of Pneumatics (*Pneumaticorum libri tres*, Naples, 1601) of the Neapolitan physicist—an edition to which he adds several passages that he had from the mouth of the author himself:

"Make a glass or tin box, and form an aperture in the bottom, through which will pass the neck of a distilling flask containing one ounce or two ounces of water. The neck must be cemented to the bottom of the box in such a manner that nothing can escape thereby. From this same bottom let there start a conduit whose opening nearly touches it, the interval being just that which is necessary to allow the water to flow into it. Let this conduit pass through an aperture in the cover of the box and extend outside to a small distance from the surface. The box is to be filled with water through a funnel that must afterward be tightly corked, so that no air shall be allowed to escape. Finally, let the flask be placed upon the fire and be gradually heated, and then the water converted into steam will press the water in the box, and force it, and cause it to make its exit through the conduit and flow to the exterior.

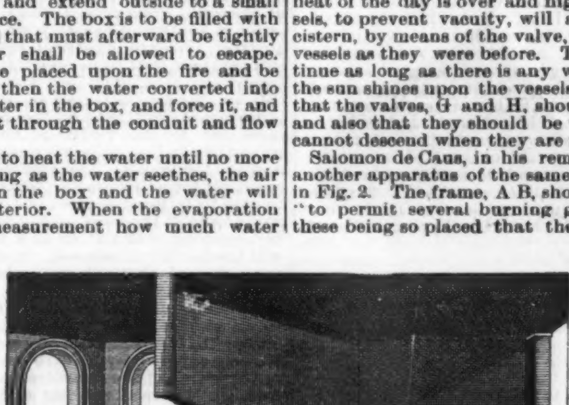


FIG. 2.—DE CAUS APPARATUS FOR RAISING WATER BY SOLAR HEAT.

"Continue ever thus to heat the water until no more of it remains, and so long as the water seethes, the air will press the water in the box and the water will make its exit at the exterior. When the evaporation is finished, find by measurement how much water has been forced from the box, and it will be seen that as much remains as has made its exit from the flask, and one may conclude from the quantity of water that has flowed out how much air it was converted into."

Salomon de Caus (*Les raisons des forces mouvantes*, Paris, 1634, liv. I., probl. xiii) gives an analogous application to the movement of water through the *heat of the sun*. He calls his apparatus the "Continuous fountain" (Fig. 1), and describes it thus:

"This machine will have a great effect in warm places, like Spain and Italy, inasmuch as the sun appears almost every day in such places with great heat, and especially in summer. The construction of it will be as follows: It is necessary to have four copper vessels well soldered all around, which should be each about a foot square and eight or nine inches in height. These vessels will be marked (see Fig. 1) A, B, C and D, and there will be a tube, E, placed upon them to which will be soldered four branches, F. These branches will be soldered to the top of the vessels, and extend nearly to the bottom of each one of them. After this it is necessary to solder to the center of the tube a valve, G, made and placed in such a way that when the water is making its exit from the vessels it can open, and when it has made its exit, it (the valve) can be closed tightly. It is necessary also to have another tube, P, under the vessels, and which also will have four branches that will be soldered against the bottom of the vessels, and likewise a valve, H, at the end of which there will be a tube that will descend to the bottom of the water, which latter will be in a cistern, I. There will be also in one of the vessels an aperture, M.

It will be necessary to expose the machine in a place where the sun can shine upon it, and then to pour water into the vessels through the aperture, M. This water will enter all the vessels through the tubes, and the said vessels must be filled one-third full. The air that was in the place of the water will make its exit through the vents, 3, 4, 5, 6. Afterward it will be necessary to well cork the latter, so that no air can escape from the vessels; and while the sun is shining upon the machine, a compression will take place because of the heat, . . . and this will cause the water to rise in all the vessels to the pipe, E, and make its exit through the valve, G, and the tube, N, then fall into the basin, O, and thence into the cistern, I; and as a quantity of water will have made its exit through the violence of the sun's heat, the valve, G, will close, and after the heat of the day is over and night supervenes, the vessels, to prevent vacuity, will attract water from the cistern, by means of the valve, H I, in order to fill the vessels as they were before. This movement will continue as long as there is any water in the cistern and the sun shines upon the vessels; and it must be noted that the valves, G and H, should be made very tight, and also that they should be very tight, so the water cannot descend when they are mounted."

Salomon de Caus, in his remarkable work, describes another apparatus of the same kind that we represent in Fig. 2. The frame, A B, should be so constructed as "to permit several burning glasses to be set into it, these being so placed that the rays converging from them may be concentrated upon the vessels, which, being heated by the sun, will cause the water to rise in large quantity."

De Caus recommends that a tube, C D, be passed through a wall, in order to lead the water to a small fountain on the other side.—*La Nature.*

THE LONDON, OHIO, WATER SUPPLY SYSTEM.

THE water supply system at London, Ohio, was completed and put in operation last December. The works were constructed by John P. Martin, of the Ohio Valley Water and Contracting Company, assisted by Frank C. Smith, C. E., engineer of the company, under a twenty years' franchise, by the terms of which the city pays $5,000 yearly rental for 100 hydrants, the guaranteed quantity of water to be supplied being 1,500,000 gallons daily.

The pumping station and stand pipe are situated on a plot of land on West High Street. The pumping station is a brick structure, built on a 10 foot stone foundation. It is forty feet square, has an ornamental slate roof, and is practically fireproof. The ventilator cupola is surmounted with a finial and weather vane. The octagon brick smokestack is 65 feet high, and has a painted iron cap. The pumping room is cemented on the sides and floor, the latter being ten feet below the surface. Balconies have been constructed for the convenience of visitors. The power consists of one compound duplex pumping engine of 1,200,000 gallons and one high pressure duplex engine of 800,000 gallons daily capacity, both of which can furnish 500,000 gallons more daily than called for by the contract. These pumps are of the Gordon make, of Hamilton, O., and were furnished by the Boughen Engineering Company, of Cincinnati. The boiler room has two 54 inch 12 foot steel boilers, fed by a strong pump of the same make as the others. A large coal room faces one end of the boilers, while a wash room and closets are located in their rear.

The stand pipe, which rests upon a foundation of cement 8 feet thick and 38 feet in diameter, is made of rolled steel, the lower plates being ⅜ inch and the upper ¼ inch thick. It is 125 feet high and has a diameter of 20 feet and capacity of 295,000 gallons. This height gives a pressure through the pipes of 55 pounds to the square inch. It was built by Armstrong Bros., of Springfield, O., who also furnished the boiler in the pumping station.

The water supply, which is of exceptional purity, comes from three artesian wells.

The well known as No. 1 is located near the trestle at Oak Run Creek. It is 70 feet in depth and yields about 800,000 gallons every twenty-four hours. It has no cistern. The analysis of 100,000 parts of the water from the well gave the following result: Free ammonia 0·0582; albuminoid ammonia, 0·0086; chlorine, 0·45; oxygen consumed, 0·16; nitrous acid, none; total solids, 43·6.

No. 2, to the northwest of the stand pipe, is 171 feet deep. When in course of construction the water rose 26½ feet above the surface, and this natural flow was utilized to fill the first three rings of the stand pipe. This well now has a storage basin 31 feet in diameter built immediately around it to a depth sufficient to hold 100,000 gallons. Over this tank is a twelve-sided frame building with a pagoda roof.

Well No. 3 flows 600,000 gallons of pure water per day. Its depth is 165 feet and it has been flowing a 5½ inch stream twelve feet above the ground. A cistern, 43 feet in diameter and 20 feet deep, with a capacity of 200,000 gallons, stores the water. The surplus flow of this well is conveyed by pipes to the near-by ice pond. This cistern is covered over with a water tight floor, except in an 18 foot circular building supported on iron pillars. On the inside of this structure is a three-foot walkway, supplied with railing and balcony, from which the visitor can view the wonderful flow and capacious cistern.

The arrangement of the pumping plant is such that one or both pumps can be used, likewise the boilers. Ordinary service pressure is given from the stand pipe. In case of fire an electric alarm notifies the engineer, and the pumps are started. The pressure can be increased to 200 pounds per square inch if necessary. The combined volume of water ready at all times for use is 600,000 gallons, with two flowing wells and one ordinary well to keep up the supply. The valve system is so complete that it is not only easy to cut off or draw from any one cistern or all, but also from any one well or more.

The distributing system includes 11 miles of 4 to 14 inch cast iron pipe, and the 101 double nozzle hydrants are so distributed that with 200 feet of hose any building in the town can be reached by a stream.

The system of mains is subdivided by seventy-five valves, or water gates, in such a way that any portion of it can be disconnected from the whole at will. Thus repairs may be made without occasioning more than a temporary local inconvenience.

The pipe was furnished by the Addyston Pipe and Steel Co., of Cincinnati, and the valves and hydrants by the Bourbon Brass and Copper Works, of the same city. The pipe laying was done by R. B. Carothers, of Newport, Ky.—*Fire and Water.*

THE MIRAMICHI FIRE OF 1825.

ABRAHAM GESNOR'S "New Brunswick" contains an account of the forest fires in Northumberland county, New Brunswick, which desolated the district of Miramichi, October 7, 1825. In only one hour, New Castle, the present capital, Douglaston, and all the villages along the north side of the river Miramichi were entirely destroyed; 160 persons and 875 cattle were said to have perished, and nearly 600 buildings were destroyed.

The preceding summer had been excessively hot throughout North America, and there had been little rain to refresh the parched and withered vegetation; violent forest fires had raged in Canada, Nova Scotia and Maine, and although New Brunswick had not escaped, the inhabitants of the province were not apprehensive, on account of their remoteness from the destructive element.

The intense heat of the season did not pass away with the summer, but was still unabated on October 7. That day was perfectly calm, and peculiarly sultry, inducing a condition of lassitude. The heavens wore a purple tint, and clouds of black smoke hovered over Miramichi. Still none of these signs was ominous to her people, who might have taken warning from the cattle in the pastures, for they became terrified and gathered in groups, and even the wild animals of the wilderness rushed out and sought refuge among the tamer breeds.

"At seven o'clock P. M. a brisk gale sprang up, which by eight o'clock had increased to a swift hurricane from the west, and soon afterward a loud and almost appalling roar was heard, with explosions and a crackling like that of discharges of musketry. The air was filled with burning pieces of wood and cinders, which were driven along by the gale, igniting everything upon which they fell. The roaring grew louder, and sheets of flame seemed to pierce the sky." It is un-

necessary to give any details of the terror, horror and despair which seized upon all living creatures. "The whole surface of the earth was on fire, and everything of a combustible nature united in sending up the last broad flame, which laid the country, with its towns, villages and settlements, in heaps of smouldering ashes." Fishes perished in the streams from the intense heat of the burning forests that chanced to overhang them, nor did the swift wings of birds offer them a means of escape. The famous conflagration was not confined to the district of Miramichi, but overspread an area of 6,000 square miles.

WILLIAM CROOKES, F.R.S.

AMONG contemporary men of science, few, if any, can present a more distinguished and varied career of research and discovery than the newly elected president of the Institution of Electrical Engineers, William Crookes. Though belonging by parentage, like Faraday, to Yorkshire, he was born in London in 1832, just in time, as he says, to escape having his mind ossified by examinations. His tendency to experimental science led him when a boy to the then comparatively virgin field of photography. In 1848 he entered the Royal College of Chemistry, as a pupil of the illustrious Dr. Hofmann. Here, at the early age of seventeen, he gained the Ashburton scholarship. After two years' study he became first the junior and then the senior assistant to Dr. Hofmann. In 1854 he was appointed to superintend the Meteorological Department of the Radcliffe Observatory at Oxford. In the following year he became teacher of chemistry at the Science College, Chester. In 1859 he founded the *Chemical News*, of which he is still the proprietor, and which remains the organ of chemical science in this country. In 1864 he became editor also of the *Quarterly Journal of Science*, which he conducted down to 1880.

Prof. Crookes entered upon original research while still at the Royal College of Chemistry, his first results being a paper on the seleno-cyanides, which he communicated to the Chemical Society in 1851, and which appeared in the *Journal* of the society in the same year. From this paper, the greater part of the author's subsequent researches, multiform as they may seem, follow in legitimate filiation. His investigations on the compounds of selenium led him in 1861 to examine certain residues from the sulphuric acid works of Tilkerode, where he met with a then unknown substance which on thorough scrutiny proved to be the new metallic element thallium. In June, 1862, and in February, 1863, he submitted to the Royal Society an elaborate account of the newly discovered element, its sources, distribution, the methods for its extraction and purification, as well as of its characteristics, physical and chemical. He showed its occurrence in various kinds of iron and copper pyrites, in crude sulphur as well as in flue dusts. His election as a fellow of the Royal Society followed the same year. In 1864 he presented to the Chemical Society, of which he had been a fellow since 1850, an exhaustive account of thallium, embodying both his own researches and those of others, and including tables of the qualitative and quantitative reactions of this metal. The research necessitated delicate spectroscopic investigations, and thus led Prof. Crookes to the study of the so-called "rare earths," which has already proved so fruitful in his hands.

In 1865 he invented an improved process for the extraction of gold and silver from their ores, based on the use of sodium amalgam in place of pure mercury. We may mention that he has recently devised a further improvement in the treatment of refractory gold ores by submitting them to the action of an alternating electric current while in contact with mercury cyanide or other mercurial salts. In the year following he was appointed by the government to experiment and report on the use of disinfectants for arresting the spread of the cattle plague (rinderpest), which was at that time ravaging many parts of England and Scotland, and occasioning widespread alarm. In 1871 he was appointed a member of the English expedition to Oran, with the object of conducting a spectroscopic examination of the phenomena manifested during a total eclipse of the sun. In the following year he presented to the Royal Society a full account of his experiments for determining the atomic weight of thallium. Among other precautions adopted to insure accuracy, we may mention that he executed the necessary weighings by means of a balance which admitted of being manipulated in a vacuum.

In the same year he began his investigations on "Repulsion Resulting from Radiation." To this question his attention had been drawn in consequence of observations made when weighing heavy pieces of glass apparatus in his vacuum balance while determining the atomic weight of thallium. He communicated a memoir on this subject to the Royal Society in December, 1873, and between that time and 1880 he produced eight other papers on collateral questions. These phenomena are manifested by means of the radiometer, otherwise known as the "light mill." This instrument is capable of serving to measure the intensity of solar radiations, though not, it must be remembered, of light alone.

In 1875 Prof. Crookes received from the Royal Society a royal medal in recognition of his chemical and physical researches. In 1876 he was elected a vice-president of the Chemical Society, and in the following year he became a member of the Council of the Royal Society. In 1877 he was remarkably active. He devised the otheoscope, a modified form of the radiometer, and continued the study of repulsion derived from radiation, presenting his results to the Royal Society. He had succeeded in obtaining a vacuum so nearly approaching perfection that the pressure in it is only 0·4 millionth of an atmosphere. The result was effected by means of an improved Sprengel pump. The study of these high vacua led to a twofold result: on the one hand it was found that at such extreme states of rarefaction gases lose their ordinary properties and pass into a fourth or ultra-gaseous state, which Prof. Crookes has designated as that of "radiant matter." On the other hand, they rendered the electrical glow lamp a practical possibility. Prof. Crookes' house in Kensington Park Gardens, electrically lighted in 1881, was, we believe, the first house in London fitted up with the electric light. It may be interesting to state that the wires were chiefly laid with his own hands. To meet the difficulty of obtaining carbon filaments for the glow lamps, not possessing the structure of the material from which they were made, Prof. Crookes dissolved cellulose in a strong solution of ammonium copper sulphate, dried up the solution into sheets, dissolved out the copper, and used the horn-like material remaining for filaments. The lamps in the inventor's house fitted with such filaments remain still in good working condition. In 1881 he acted as a juror at the International Exhibition of Electricity in Paris. His system of lamps was, of course, debarred *ex-officio* from competing, but his fellow jurors remarked in their award on the four systems of lamps before them, that: "None of them could have succeeded had it not been for those extreme vacua which Prof. Crookes has taught us to manage." The "Crookes incandescent lamp" has, for a variety of reasons, not come into general use. The company which undertook their manufacture had not sufficient capital to produce them on the large scale. Another company took the invention up, but further operations were stopped by the judicial decision in the Edison-Swan *vs.* Brush case. We are not yet sufficiently removed from the days when a judge could rule that "*in a liberal construction, copper is tin.*"

In 1880 the French Academy of Sciences conferred upon Prof. Crookes an extraordinary prize of 3,000 fr. and a gold medal in appreciation of his researches in molecular physics and on radiant matter.

On three successive occasions, namely, in 1877, 1878, 1883, Prof. Crookes was selected by the Royal Society to deliver the Bakerian lecture. On the first occasion he discussed the "Illumination of Lines of Molecular Pressure and the Trajectory of Molecules," his discourse being generally regarded as a model of deep thought and extreme experimental skill. His second Bakerian lecture summarized his experiments and observations of "Radiant Matter." His third Bakerian lecture, delivered on May 24, 1883, was devoted to "Radiant Matter Spectroscopy: A New Method of Spectrum Analysis." This naturally leads to his researches on the rare earths, with which he has been engaged for several years, and which promise to lead to most important results. On attacking yttria by the process of "fractionation," he finds that it is resolved into at least five elements, possibly more, and there is no certainty that this analysis has reached completion.

The new elements, or as Prof. Crookes calls them provisionally, "meta elements," differ more in their physical than in their chemical properties. It is especially remarkable that substances which have been found capable of decomposition may still possess a definite atomic weight. On studying closely the phenomena of these rare earths, Prof. Crookes has been led to the conclusion that the bodies which have generally been accepted as elements are not primordially distinct or independent, but have been formed by a process of evolution remotely analogous to that which we now recognize as having been at work in the formation of organic species. These views, a forecast of the "Chemistry of the Future," were given to the world in the presidential address which Prof. Crookes delivered before the chemical section of the British Association at the Birmingham meeting, under the title "The Genesis of Elements." He further developed the same subject in his presidential addresses to the Chemical Society in 1888 and 1889, and it constitutes without doubt his grand contribution to the philosophy of the science. In the experiments which pointed to these conclusions electricity has constantly been appealed to for the diagnosis of the new bodies encountered. In 1885, the Society of Arts awarded him a gold medal "for his improvements in apparatus for the production of high vacua, and for his invention of the radiometer." In 1888 he was awarded by the Royal Society the Davy medal, for "his investigations on the behavior of substances under the influence of the electric discharge in a high vacuum."

The contributions of Prof. Crookes to the literature of science have been both numerous and important. We are indebted to him for the "Third Report of the Cattle Plague Commission;" for a book on "The Manufacture of Beetroot Sugar in England" (1870), "A Handbook of Dyeing and Calico Printing" (1874), "Select Methods in Chemical Analysis" (1873; 2d edition, 1886); a manual of "Dyeing and Tissue Printing," being one of the technological handbooks prepared for the examinations of the City and Guilds of London Institute (1882). In conjunction with Prof. Odling and Dr Tidy, he issues reports on the composition and quality of the water supplied to London (1881–1890). He has also written a "Solution of the Sewage Question" and "The Profitable Disposal of Sewage." He has edited the English version of Kerl's "Treatise on Metallurgy" and the three last editions of Mitchell's "Manual of Practical Assaying." He has translated into English and edited Reimann's "Aniline and its Derivatives;" Wagner's great work on "Chemical Technology" (second edition of which is in course of preparation); Auerbach's "Anthracene and its Derivatives;" and Ville's "Artificial Manures," the second edition of which appeared in 1882. A list of the memoirs which he has contributed to the journals of the Royal and the Chemical societies would far exceed our limits.

In all public questions in which science is concerned he has taken a prominent and useful part. He is recognized as an authority on sanitary reforms, especially as regards the purification of sewage and the improvement of the condition of rivers.

He has continually, and so far successfully, opposed the adoption of the arbitrary "proposals" of the Rivers Pollution Commissioners, and he sees no ground for the discontinuance of the present water supply of London. In leaders and reviews he has steadily condemned the system of examinations prevalent in England as calculated to destroy original thought. He is one of the signatories of Mr. Auberon Herbert's "Protest against the Sacrifice of Education to Examination." Wherever the claims of science or the rights of scientific men are neglected, Prof. Crookes is always ready to speak out. His career conveys an important lesson for the student. It is not merely the exceptionally suggestive character of his mind and his promptitude in appreciating every phenomenon presenting itself which have enabled Professor Crookes to carry out such a quantity of important work. He possesses that "infinite capacity for taking pains," and that methodical spirit, without which genius and learning are thrown to waste.

Every research in progress and in particular every result is duly recorded in a special note book. References to any work by other scientists bearing on the same or collateral subjects are registered and every book in his extensive library, and every document in the pigeon holes of his work table are carefully indexed for reference. Without the economy of time and energy thus effected, not half of his work could have been accomplished.—*The Electrician.*

ELECTRICITY IN TRANSITU; FROM PLENUM TO VACUUM.*

By Prof. WILLIAM CROOKES, F.R.S.

INTRODUCTION.

WHILE steadily bearing in mind that I have the honor to address a society, not only of physicists, but of electrical engineers, I shall not, I hope, be out of order in venturing to call your attention to a purely abstract phase of electrical science. Numberless instances show that pure research is the abundant source from which spring endless streams of practical applications. We all know how speculative inquiry into the influence of electricity on the nervous systems of animals led to knowledge of current electricity, and ultimately to the priceless possession of the telegraph and the telephone. The abstract study of certain microscopic forms of parasitic vegetable life has enabled us to give to fermented solutions of sugar the exact flavor and aroma of the most highly prized wines, and probably, ere long, will put us in a position to increase at will the fertility of the soil. In a different direction the same class of abstract researches applied to medical science has brought us within measurable distance of the final conquest over a large class of diseases hitherto incurable; and without egotism I may, perhaps, be allowed to say that my own researches into high vacua to some extent have contributed to the present degree of perfection of the incandescent lamp. Surely, therefore, while eagerly reaping and storing the harvest of practical benefits, we must not neglect to scatter more seed for future results, perchance not less wonderful and valuable.

In another respect I deviate to some extent from the course taken by many of my predecessors. I am about to treat electricity, not so much as an end in itself, but rather as a tool, by whose judicious use we may gain some addition to our scanty knowledge of the atoms and molecules of matter, and of the forms of energy which by their mutual reactions constitute the universe as it is manifest to our five senses.

I will endeavor to explain what I mean by characterizing electricity as a tool. When working as a chemist in the laboratory, I find the induction spark often of great service in discriminating one element from another, also in indicating the presence of hitherto unknown elements in other bodies in quantity far too minute to be recognizable by any other means. In this way chemists have discovered thallium, gallium, germanium, and numerous other elements. On the other hand, when examining electrical reactions in high vacua, various rare chemical elements become in turn tests for recognizing the intensity and character of electric energy. Positive and negative electricity effect respectively different movements and luminosities. Hence the behavior of the substances upon which electricity acts may indicate with which of these two kinds we have to deal. In other physical researches both electricity and chemistry come into play simply as a means of exploration.

In submitting to you certain researches in which electricity is used as a tool, or as a means of bringing within scope of our senses phenomena that otherwise would be unrevealed, I must for a moment recall to your minds the now generally accepted theory of the constitution of matter.

KINETIC THEORY OF GASES.

Matter at its ultimate degree of extension is conjectured to be not continuous, but granular. Maxwell illustrates this view as follows: To a railway contractor driving a tunnel through a gravel hill, the gravel may be viewed as a continuous substance. To a worm, wriggling through gravel, it makes all the difference whether the creature pushes against a piece of gravel or directs its course between the interstices. To the

* Presidential address before the Institution of Electrical Engineers, London.

worm, therefore, gravel seems by no means homogeneous and continuous.

With speculations as to the constitution of liquid and solid matter I need not trouble you, but will proceed at once to the third or gaseous state of matter.

The kinetic theory of gases teaches that the constituent molecules dart in every possible direction with great but continually varying velocities, coming almost ceaselessly in mutual collision with each other.* The distance each molecule traverses without hitting another molecule is known as its *free path*; the average distance traversed without collision by the whole number of molecules of a gas at any given pressure and temperature is called the *mean free path*. The molecules exert pressure in all directions, and are only restrained by gravitation from dissipating themselves into space. In ordinary gases, the length of the mean free path of the molecules is exceedingly small compared with the dimensions of the vessel, and the properties we then observe are such as constitute the ordinary gaseous state of matter, which depends upon constant collisions. But if we greatly reduce the number of molecules in a given extent of space, the free path of the molecules under electric impulse is so long that the number of their mutual collisions in any given time in comparison with the number of times they fail to collide may be disregarded. Hence the average molecule can carry out its own motions without interference. When the mean free path becomes comparable to the dimensions of the containing vessel, the attributes that constitute gaseity shrink to a minimum, the matter attains the ultra-gaseous or "radiant" state, and we arrive at a condition where molecular motions under electrical impulse can easily be studied.

The mean free path of the molecules of a gas increases so rapidly with progressive exhaustion that while that of the molecules of air at the ordinary pressure is only 1-10000 of a millimeter, at an exhaustion of a hundred-millionth of an atmosphere—a point (which with present appliances is easy to attain) corresponding to the rarefaction of the air 90 miles above the earth's surface—the mean free path will be about 30 feet; while at 200 miles above the earth it will be 10,000,000 miles, and millions of miles out in the depths of space it will become practically infinite. I could go on speculating in spite of Aristotle, who said: "Beyond the universe there is neither space, nor vacuum, nor time."

In discussing the motions of molecules we have to distinguish the *free* path from the *mean free path*. Nothing is yet known of the *absolute* length of the free path nor of the *absolute* velocity of a molecule. For anything we can prove to the contrary, these values may vary almost from zero to infinity. We can deal only with the *mean* free path and the *mean* velocity.

THE VACUUM PUMP.

As most of the experiments I put before you tonight are connected with high vacua, it is not out of place to refer to the pump by means of which these tubes are exhausted. Much has been said lately in recommendation of the Geissler pump and its many improvements, but I am still strongly in favor of the Sprengel, as with it I have obtained greater exhaustion than with any other. I should like to point out that the action does not stop when we come to see air specks passing down the tubes, but continues long after this point has been passed. Neither is the non-conducting vacuum, so easily obtained by the Sprengel pump, due in any way to the presence of mercury vapor, since non-conduction can be obtained just as rapidly when special precautions have been taken to keep mercury vapor out of the tubes.

One of the great advantages of the Sprengel pump over all others lies in the fact that its internal capacity need not exceed a few cubic centimeters, and there is, therefore, much less wall surface for gases to condense upon. I have brought the very latest modification of this form of pump here to-night, and you will have an opportunity of seeing it in action and of measuring with the McLeod gauge the rarefaction it produces.†

THE PASSAGE OF ELECTRICITY THROUGH RAREFIED GAS.

The various phenomena presented when an induction spark is made to pass through a gas at different degrees of exhaustion point to a modified condition of the matter at the highest exhaustions. Here are three exactly similar bulbs, the electrodes being aluminum balls, and the internal pressures being respectively 75 millimeters, 2 millimeters and 0·1 millimeter. If I pass the induction current in succession through the bulbs, you will perceive in each case very different luminous phenomena. Here is a slightly exhausted tube (Fig. 1),

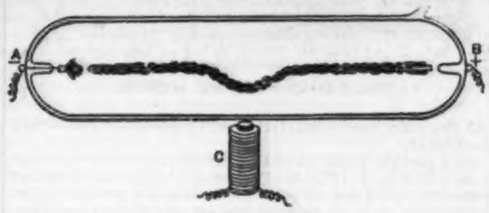


FIG. 1.—P = 75 MM.

like the first in the series just exhibited (75 millimeters); the induction spark passes from one end to the other, A, B, and the luminous discharge is seen as a line of light, acting as a flexible conductor. Under the tube I have an electromagnet, C, and on making contact the line of light dips in the center down to the poles of the magnet, and then rising again proceeds in a straight line. On reversing the current the line of light curves upward. Notice that the action of the magnet in this case is only local.

In a highly exhausted tube the action is quite otherwise. Such a tube is before you (Fig. 2), and in it I

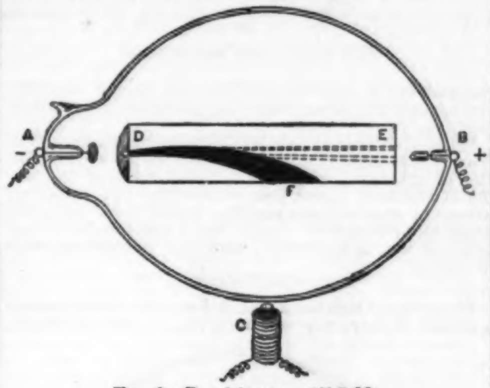


FIG. 2.—P = 0.1 MM. = 131.5 M.

have carried the exhaustion to a high point (0·1 millimeter). I pass the induction current, and you perceive the electrified molecules, like the line of light in the first tube, also move in straight lines, and make their path apparent by impinging on a phosphorescent screen, D E. If, however, I submit them to the action of the magnet, c, their behavior is different. The line dips down to F, but does *not* recover itself. It seems that in the tube first shown we have to do with the average behavior of the molecules of gas in its totality. In the second case, where the gas has been greatly attenuated, we are merely concerned with the behavior of the individual molecules of which it was originally composed.

THE STRATIFIED DISCHARGE.

When the gas is rarer than is necessary to give the flexible line of light, as shown in the first experiment, the luminosity is plainly discontinuous or, as it is termed, stratified.

A very good illustration of this fact may be taken from the moving crowd in any much frequented street, say Fleet street. If, at some time when the stream of traffic runs almost equally in both directions, we take our stand at the window from which we can overlook the passing crowd, we shall notice that the throng on the foot-way is not uniformly distributed, but is made up of knots—we might almost say blocks—interrupted by spaces which are comparatively open. We may easily conceive in what manner these knots or groups are formed. Some few persons walking rather more slowly than the average rate slightly retard the movements of others whether traveling in the same or in an opposite direction. Thus a temporary obstruction is created. The passengers behind catch up to the block and increase it, and those in front, passing on unchecked at their former rate, leave a comparatively vacant space. If a crowd is moving all in the same direction, the formation of these groups becomes more distinct. With vehicles in crowded streets, the result, as every one may have remarked, will be the same.

Hence mere differences in speed suffice to resolve a multitude of passengers into alternating gaps and knots.

Instead of observing moving men and women, suppose we experiment on little particles of some substance, such as sand, approximately equal in size. If we mix the particles with water in a horizontal tube and set them in rhythmical agitation, we shall see very similar results, the powder sorting itself with regularity into alternate heaps and blank spaces.

If we pass to yet more minute substances, we observe the behavior of the molecules of a rarefied gas when submitted to an induction current. The molecules here are free, of course, from any caprice, and simply follow the law I seek to illustrate, and though originally in a state of rampant disorder, yet under the influence of the electric rhythm they arrange themselves into well defined groups or stratifications; the luminosities show where arrested motion with concomitant friction occurs, and the dark intervals indicate where the molecules travel with comparatively few collisions.

PARTY-COLORED STRATIFICATIONS.

As another illustration of stratifications in a moderately exhausted tube (P=2 millimeters), I will take the case of hydrogen prepared from zinc and sulphuric acid after being passed through various purifying agents, dried in the usual manner, and exhausted with a mercury pump (Fig. 3). I pass the induction current, and we see that the stratifications are tricolored blue, pink and gray. Next the negative pole, A, is a luminous layer, then comes a dark interval or Faraday's dark space (see below), and after this are the stratifications, the front component (*b*) of each group blue, the next (*c*) pink, and the third (*d*) gray. The blue disks are somewhat erratic. At a certain stage of ex-

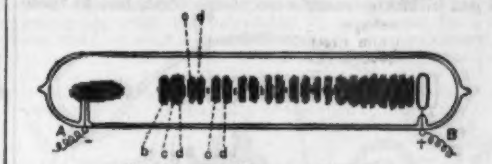


FIG. 3.—P = 2.0 MM. = 2,630 M.

haustion all the blue components of the stratifications suddenly migrate to the front, forming one bright blue disk, and leaving the pink and gray components by themselves.

The tube before you (Fig. 4) is at this particular stage of exhaustion, and on passing the current you observe the blue disk only (*b*) is in front. When the tube contains a compound gaseous residue of this kind, the form of stratifications can be very considerably altered by varying the potential of the discharge. This alteration in the forms of stratification was first pointed out by Gassiot (1865, "B. A. Abstracts," p. 15), who gave very

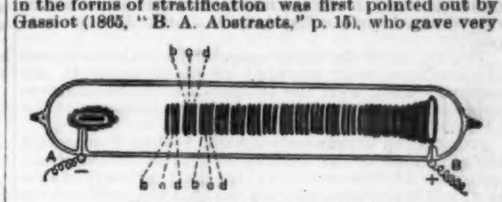


FIG. 4.—P = 2.0 MM. = 2,630 M.

full descriptions and drawings of the alterations produced by putting in resistances of various lengths of distilled water. That the alteration depends simply upon the difference of potential the following experiment pretty clearly shows: Here is a tube giving on my coil the colored stratification usually attributed to the presence of residual hydrogen, but which I find is due to a mixture of hydrogen, mercury, and hydrocarbon vapors. Now, by altering the break so as to produce frequent discharges of lower potential, you see the stratifications gradually change in shape and become all pink; again altering the break so as to send less rapid discharges at a much higher potential, once more we get the colored stratifications. When in this state, if we introduce a water resistance into the circuit so as to damp down the potential, exactly the same thing happens. The blue disk is caused by mercury; its spectrum is that of mercury only, without even a trace of the bright red line of hydrogen. Experiments not yet finished make it very probable that the pink disks are due to hydrogen, and that the gray disks indicate carbon.

The tube you have just seen contains nothing but hydrogen, mercury, and a minute trace of carbon; but with all the resources at my command I have not been able to get hydrogen quite free from impurity. Indeed, I do not think absolutely pure hydrogen has ever yet been obtained in a vacuum tube. I have so far succeeded as to completely eliminate the mercury, and almost completely to remove the trace of carbon. On the table is such a tube giving uniformly pink stratifications, and showing no blue or gray disks with any potential of current.

THE DARK SPACE.

After the stratification stage is passed, we come to a very curious phenomenon, the so-called "dark space." Studying electrical phenomena in gases, in the year 1838, Faraday* pointed out a break in the continuity of the luminous discharge separating the glow of the positive electrode from that of the negative. This he called "the dark space." It is seen in tubes containing gas only slightly rarefied, as in this tube (Fig. 5, P=6 millimeters), where you will observe that the

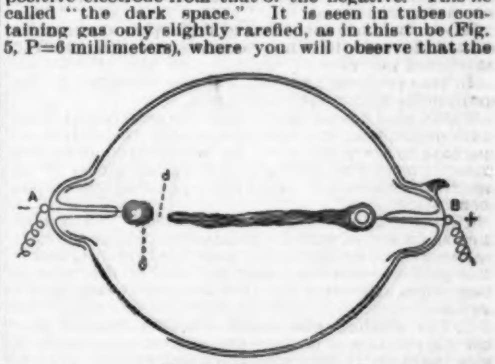


FIG. 5.—P = 6.0 MM.

positive glow, extending as a pink streak from the positive electrode, B, ends about 10 millimeters before the spot of blue light, C, representing the negative glow. This gap, or non-luminous hiatus, D, is Faraday's "dark space."

Separating the negative glow from its electrode is another space. In this tube it is so small that the glow appears to be in actual contact with the electrode, but on exhausting a little further it rapidly separates; and in the next tube (Fig. 6), containing air at a little less pressure (P=3 millimeters), this dark space, E, has extended so as to remove the negative glow about four millimeters from the electrode, A. It is with this second dark space that I particularly wish to deal tonight. Therefore I shall refer to it as the "dark space," meaning always that in a negative glow.

In the experiment just shown with hydrogen stratifications the contents of the tube under the electric discharge still obey the laws following from the aver-

* I speak of "collisions," as these are the generally accepted *substrata* of the kinetic theory. But Prof. Silvanus P. Thompson reminds me that Boltzmann some years ago proposed a modification of the kinetic theory which to me seems a vast improvement on the somewhat bald notion of molecular collisions. According to Boltzmann's view, in a so-called "collision" the molecules do not actually bounce against one another, but merely fly round in two interlocking hyperbolic paths. The effect for all external purposes will be the same as if they collided, because of the extreme minuteness of the curved part of the paths. The gain in thus regarding the matter is that such hyperbolic paths are quite consistent with obedience to the ordinary laws of gravitational attraction; whereas the collision theory needs for its explanation that when molecules come very near together, they should exhibit a repulsion varying inversely as the fifth power of the distance between them.

† My measurements of high vacua have all been taken with the beautiful little gauge devised by Professor McLeod. Unmerited discredit has recently been cast on this gauge, the principal fault alleged being its inability to distinguish between the tension of the permanent gas and that of the mercury vapor present. Now it is evident that, under ordinary circumstances, the tension of mercury vapor may be disregarded, as it will be the same on both sides of the gauge; and it will be only in cases where no mercury is present on one side of the gauge that a slight error is introduced. It is, however, very difficult to devise and successfully experiment with apparatus in which a trace of mercury vapor shall not enter, and it is not likely that an experimentalist who would be working with such mercury-free apparatus would attempt to use the gauge without remembering that in this special case the indications would be incorrect. To use the McLeod gauge requires much patience and some amount of experience, but I have always found it trustworthy to register exhaustions far beyond the millionth of an atmosphere. I can adduce circumstantial evidence of the accuracy of its readings at these high vacua. In the year 1881 I read a paper before the Royal Society on "The Viscosity of Gases at High Exhaustions" (*Phil. Trans.*, 1881, p. 387), and illustrated my results in three large diagrams, on which I plotted the experimental results obtained at rarefactions up to the 0·02 millionth of an atmosphere, giving curves comparing the decrease in viscosity with that of repulsion resulting from radiation, at the different pressures. Now these curves, in the case of air, for instance, are perfectly regular and uniform in their falling off, and it is evident that this could not have been the case unless the abscissæ representing viscosity and the ordinates representing pressure were equally accurate. I am satisfied that, within narrow limits, the abscissæ of viscosity are correct to the highest point, and the conformity of experiment to theory in the shape of these curves is a conclusive proof that at as high an exhaustion as 0·02 M. the McLeod gauge is to be trusted to give accurate results within two per cent. of the truth. To give some idea what these high exhaustions mean I may mention that the highest measured exhaustion (0·02 M.) bears the same proportion to the ordinary pressure of the atmosphere that a millimeter does to 30 miles, or, in point of time, that one second bears to 0·20 month.

* "Experimental Researches in Electricity," 1838, par. 1,544.

age properties of an immense number of molecules moving in every direction with velocities of all conceivable magnitudes. But if I continue exhausting, the dark space, E, round the negative pole, A, becomes visible, grows larger and larger, and at last fills up the entire tube. The molecules at this stage are in a condition different from those in a less highly exhausted tube. At low exhaustions they behave as gas in the ordinary sense of the term, but at these

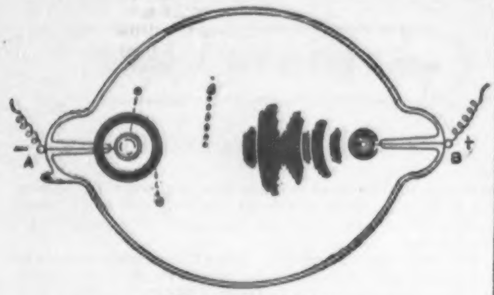


FIG. 6.—P = 3.0 MM.

high exhaustions, under electric stress, they have become exalted to an *ultra-gaseous* state, in which very decided properties, hitherto masked, come into play.

The radius of the dark space varies with the degree of exhaustion, with the kind of gas in which it has been produced, with the temperature of the negative pole, and to a less extent with the intensity of the spark.

It has been erroneously assumed that I ever said the thickness of the dark space represents the mean free path of the molecules in their ordinary condition, and it has been pointed out that the radius of the dark space is decidedly greater than the calculated mean free path of the molecules. I have taken accurate measurements of the radius of the dark space at different pressures, and compared it with the calculated mean free path of the gaseous molecules at corresponding pressures when not under the influence of electrical energy, and I find that they do not bear a constant relation one to the other. The length of the dark space is not twenty times the mean free path, as some have estimated, but a gradually increasing multiple must be taken as the exhaustion becomes greater.

EXPLORATION WITH IDLE POLES.

Wishing to learn something of the electrical condition of the matter within and without the dark space, I made a tube (Fig. 7), having besides the posi-

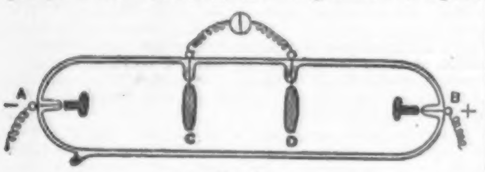


FIG. 7.

tive and negative terminals, A B, two extra intermediate poles, C and D; the tube showed that when the exhaustion was such that both the idle poles were outside the dark space, on passing the current through the tube there was a considerable difference of potential between them when measured on the galvanometer. If the exhaustion was carried so high that one of the extra poles was just on the border of the dark space, then no current passed between them. When the exhaustion was still further increased so as to inclose one of the extra poles fully in the dark space, again there was a great difference of potential between them, but the direction was reversed, the pole at highest potential now being the one formerly at lowest potential.

When the dark space had been further explored by means of a movable negative pole, I found that the effects did not depend essentially on the exhaustion, and were really due to the position occupied by the extra poles with regard to the dark space.

These phenomena are difficult to understand from mere description, and the experiments themselves are not easy to carry out so as to be visible to many at a time. I have here, however, a working model of an apparatus which will make these puzzling indications clear to all.

A cylindrical tube (Fig. 8, *a*, *b*, and *c*, P = 0·25 millimeter), furnished with the usual poles, A B, at the ends, has two extra or idle poles near together at C and D. The pole A is movable along the axis of the tube, so that when exhausted the dark space can be brought to any desired position with respect to the idle poles C and D. The shading and + and — marks roughly show the distribution of positive and negative electricity inside the tube. I start with the negative pole, A, as far as possible from either idle pole (Fig. 8, *a*). Turning on

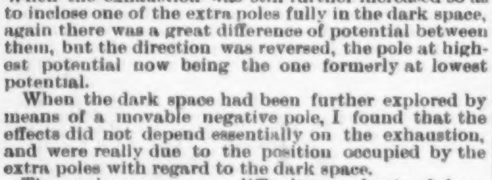


FIG. 8 A.—P = 0.25 MM. = 330 M.

the coil, you see the dark space surrounding the pole A, and the idle poles quite outside.

The shading shows that each idle pole is in the positive area, and on testing with a gold leaf electroscope it will be seen that each is charged with positive electricity. But the shading also shows more positive at C than at D, and on connecting C and D with a galvanometer the needle indicates a rush of current from C to D, D being negative to C.

The dark space is next brought to such a position that the pole, C, is well within it (Fig. 8, *b*). A change has now come over the indications. The galvanometer shows a reverse current to that which was seen on the former occasion. C is now negative and D positive,

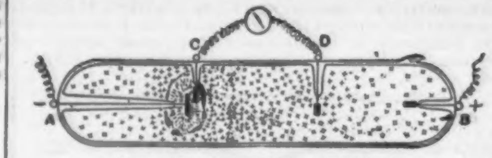


FIG. 8 B.—P = 0.25 MM. = 330 M.

but the gold leaves still tell us both poles are positively electrified.

At a certain position of the dark space, when its edge is on the pole, C (Fig. 8, *c*), a neutral state is found at which the gold leaves still show strongly positive electrifications, and no current is seen on the galvanometer. The curves below (Fig. 8, *c*) roughly show the

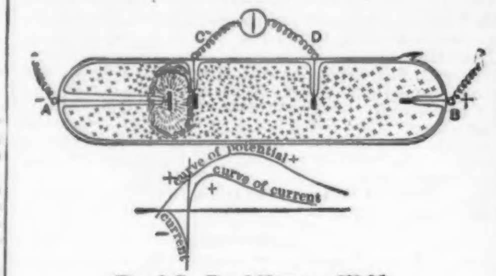


FIG. 8 C.—P = 0.25 MM. = 330 M.

rise and fall of negative and positive current at different parts of the tube, while the potential curve keeps positive.

When a substance that will phospheresce under electrical excitement is introduced into the tube, the position of greatest luminosity is found to be at the border of the dark space, just where the two opposing armies of negative and positive atoms meet in battle array and recombine. Later on I shall refer to this phenomenon in connection with the phosphorescence of yttria.

RADIANT MATTER.

By means of this tube, Fig. 9, I am able to show that a stream of ultra-gaseous particles, or radiant matter,

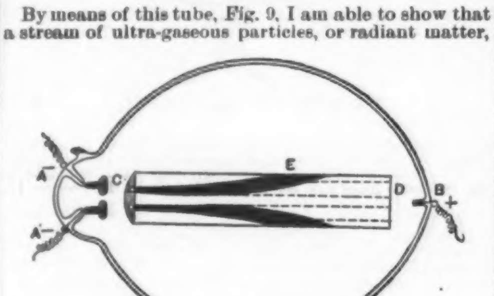


FIG. 9.—P = 0.1 MM. = 131.5 M.

does not carry a current of electricity, but consists of a succession of negatively electrified molecules whose electrostatic repulsion overbalances their electromagnetic attraction, probably because their speed along the tube is less than the velocity of light. The tube has two negative terminals, A, A′, close together at one end, enabling me to send along the tube two parallel streams of radiant matter, rendered visible by impinging them through holes in a mica diaphragm on a screen of phosphorescent substance. It is exhausted to a pressure of 0·1 millimeter. I connect one of the negative poles, A, with the induction coil, and the luminous stream darts along the tube from C to D parallel with the axis. I now connect the other negative pole, giving a second parallel stream of radiant matter. If these streams are in the nature of wires carrying a current they will attract each other, but if they are simply two streams of electrified molecules they will repel each other.

As soon as the second stream is started you see the first stream jump away in the direction, C E, showing strong repulsion, proving that they do not act like current carriers, but merely like similarly electrified bodies. It is, however, probable that were the velocity of the streams of molecules greater than that of light, they would behave differently, and attract each other, like conductors carrying a current.

To ascertain the electrical state of the residual molecules in a highly exhausted tube, such as you have just seen, I introduced an idle pole or exploring electrode between the positive and negative electrodes in such a manner that the molecular stream might play upon it. The intention was to ascertain whether the molecules on collision with an obstacle gave off any of their electrical charge.

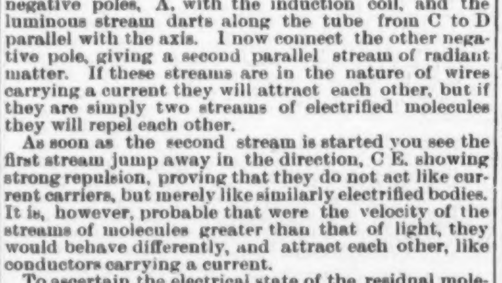


FIG. 10.—P = 0.0001 MM. = 0.13 M.

In this experiment, Fig. 10, P = 0·0001 millimeter, or 0·13 meter,* it was found that an idle pole, C, placed in the direct line between the positive and the negative poles, A B, receiving in consequence the full impact of the molecules shot from the negative pole, manifested a strong positive charge. In a variety of other experiments made to decide this question the electricity obtained was always found positive on testing with the gold leaf or Lippman's electrometer, and when the idle pole was connected to earth through a galvanometer, a current passed as if this pole were the copper element of a copper-zinc cell, indicating leakage of a current to earth, the idle pole being positive.

If, instead of sending this current to earth, the wire was connected to the negative pole of the tube, a much more powerful current passed in the same direction.

THE EDISON EFFECT.

An exactly parallel experiment has been made by Mr. Edison, Mr. Preece, F.R.S., and Professor Fleming, using instead of a vacuum tube an incandescent lamp. They found that from an idle pole placed between the ends of the filament the electricity always flowed as if the pole were the zinc element of a copper-zinc cell; having repeated their experiments, I entirely corroborate them. I get a powerful current in one direction from an idle pole placed between the limbs of an incandescent carbon filament, and one in the opposite direction from an idle pole in a highly exhausted vacuum tube. This discrepancy was extremely puzzling, and I tested with a similar result very many experimental tubes made in different ways.

The electricity obtained from an idle pole placed between the positive and negative terminals in a highly exhausted tube was always strongly *positive*, and it is only recently that continued experiment has cleared the matter up.

Some of the contradictory results are due to the exhaustion not being identical in all cases. In my vacuum tubes the direction of current between the idle pole and the earth changes from negative to positive as the exhaustion rises higher. Testing the current when exhaustion is proceeding, there is a point reached when the galvanometer deflection—hitherto negative—becomes *nil*, showing that the potential at this point is zero. At this stage the passage of a few more drops of mercury down the pump tube renders the current positive. This change occurs at a pressure of about 2 millimeters.

After this point is reached, when the induction current is passed through the tube, the walls rapidly become positively electrified, probably by the friction of the molecular stream against the glass, and this electrification extends over the surface of any object placed inside the tube. I will show you how this electrification of the inner walls of the tube acts on the molecular stream at high vacua.

In this tube, Fig. 11 (P = 0·001 millimeter or 1·3 M),

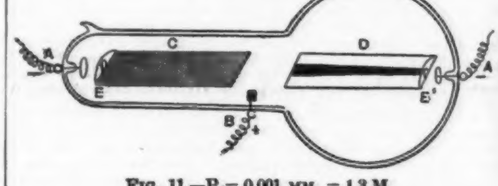


FIG. 11.—P = 0.001 MM. = 1.3 M.

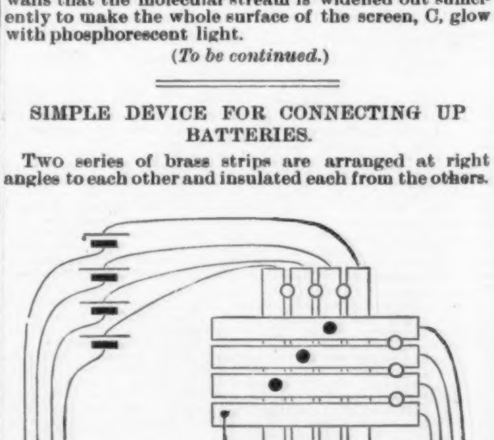
are fixed two exactly similar phosphorescent screens, C and D; at one end of each is a mica gate, E E, with a negative pole, A A′, facing it. One of the screens, C, is in the cylindrical part of the tube and close to the walls; the other, D, is in the spherical portion, and, therefore, far removed from the walls. On passing the current, the screen, D, in the globe shows a narrow sharp streak of phosphorescence, proving that here the molecules are free to follow their normal course straight from the negative pole. In the cylindrical part of the tube, however, so great is the attraction of the walls that the molecular stream is widened out sufficiently to make the whole surface of the screen, C, glow with phosphorescent light.

(*To be continued.*)

* M = one-millionth of an atmosphere.
1,000,000 M = 760 millimeters.
" = one atmosphere.

SIMPLE DEVICE FOR CONNECTING UP BATTERIES.

Two series of brass strips are arranged at right angles to each other and insulated each from the others.



DEVICE FOR CONNECTING UP BATTERY CELLS IN PARALLEL OR SERIES.

These strips are connected with the terminals of the cells to be connected, in the manner shown in the engraving, and there is a diagonal row of holes for receiving the plugs for connecting the cells in series. When these plugs are removed and plugs are inserted in the rows of holes made straight across the series of bars, the cells will be connected up in parallel.

[FROM THE ELECTRICAL WORLD.]

PHENOMENA OF ALTERNATING CURRENTS OF VERY HIGH FREQUENCY.

By NIKOLA TESLA.

ELECTRICAL journals are getting to be more and more interesting. New facts are observed and new problems spring up daily which command the attention of engineers.

In the last few numbers of the English journals, principally in the *Electrician*, there have been several new matters brought up which have attracted more than usual attention. The address of Professor Crookes has revived the interest in his beautiful and skillfully performed experiments, the effect observed on the Ferranti mains has elicited the expressions of opinion of some of the leading English electricians, and Mr. Swinburne has brought out some interesting points in connection with condensers and dynamo excitation.

The writer's own experiences have induced him to venture a few remarks in regard to these and other matters, hoping that they will afford some useful information or suggestion to the reader.

Among his many experiments Professor Crookes shows some performed with tubes devoid of internal electrodes, and from his remarks it must be inferred that the results obtained with these tubes are rather unusual. If this be so, then the writer must regret that Professor Crookes, whose admirable work has been the delight of every investigator, should not have availed himself in his experiments of a properly constructed alternate current machine—namely, one capable of giving say 10,000 to 20,000 alternations per second. His researches on this difficult but fascinating subject would then have been even more complete. It is true that when using such a machine in connection with an induction coil the distinctive character of the electrodes—which is desirable, if not essential, in many experiments—is lost, in most cases both the electrodes behaving alike; but, on the other hand, the advantage is gained that the effects may be exalted at will. When using a rotating switch or commutator, the rate of change obtainable in the primary current is limited. When the commutator is more rapidly revolved, the primary current diminishes, and if the current be increased, the sparking, which cannot be completely overcome by the condenser, impairs considerably the virtue of the apparatus. No such limitations exist when using an alternate current machine, as any desired rate of change may be produced in the primary current. It is thus possible to obtain excessively high electromotive forces in the secondary circuit with a comparatively small primary current; moreover, the perfect regularity in the working of the apparatus may be relied upon.

The writer will incidentally mention that any one who attempts for the first time to construct such a machine will have a tale of woe to tell. He will first start out, as a matter of course, by making an armature with the required number of polar projections. He will then get the satisfaction of having produced an apparatus which is fit to accompany a thoroughly Wagnerian opera. It may besides possess the virtue of converting mechanical energy into heat in a nearly perfect manner. If there is a reversal in the polarity of the projections, he will get heat out of the machine; if there is no reversal, the heating will be less, but the output will be next to nothing. He will then abandon the iron in the armature, and he will get from the Scylla to the Charybdis. He will look for one difficulty and will find another, but, after a few trials, he may get nearly what he wanted.

Among the many experiments which may be performed with such a machine, of not the least interest are those performed with a high tension induction coil. The character of the discharge is completely changed. The arc is established at much greater distances, and it is so easily affected by the slightest current of air that it often wriggles around in the most singular manner. It usually emits the rhythmical sound peculiar to the alternate current arcs, but the curious point is that the sound may be heard with a number of alternations far above ten thousand per second, which by many is considered to be about the limit of audition. In many respects the coil behaves like a static machine. Points impair considerably the sparking interval, electricity escaping from them freely, and from a wire attached to one of the terminal streams of light issue, as though it were connected to a pole of a powerful Toepler machine. All these phenomena are, of course, mostly due to the enormous differences of potential obtained. As a consequence of the self-induction of the coil and the high frequency, the current is minute, while there is a corresponding rise of pressure. A current impulse of some strength started in such a coil should persist to flow no less than four ten-thousandths of a second. As this time is greater than half the period, it occurs that an opposing electromotive force begins to act while the current is still flowing. As a consequence, the pressure rises as in a tube filled with liquid and vibrated rapidly around its axis. The current is so small that, in the opinion and involuntary experience of the writer, the discharge of even a very large coil cannot produce seriously injurious effects; whereas, if the same coil were operated with a current of lower frequency, though the electromotive force would be much smaller, the discharge would be most certainly injurious. This result, however, is due in part to the high frequency. The writer's experiences tend to show that the higher the frequency the greater the amount of electrical energy which may be passed through the body without serious discomfort; whence it seems certain that human tissues act as condensers.

One is not quite prepared for the behavior of the coil when connected to a Leyden jar. One, of course, anticipates that since the frequency is high the capacity of the jar should be small. He therefore takes a very small jar, about the size of a small wine-glass, but he finds that even with this jar the coil is practically short-circuited. He then reduces the capacity until he comes to about the capacity of two spheres say ten centimeters in diameter and two to four centimeters apart. The discharge then assumes the form of a serrated band exactly like a succession of sparks viewed in a rapidly revolving mirror; the serrations, of course, corresponding to the condenser discharges. In this case one may observe a queer phenomenon. The discharge starts at the nearest points, works gradually up, breaks somewhere near the top of the spheres, begins again at the bottom, and so on. This goes on so fast that several serrated bands are seen at once. One may be puzzled for a few minutes, but the explanation is simple enough. The discharge begins at the nearest points, the air is heated and carries the arc upward until it breaks, when it is re-established at the nearest points, etc. Since the current passes easily through a condenser of even small capacity, it will be found quite natural that connecting only one terminal to a body of the same size, no matter how well insulated, impairs considerably the striking distance of the arc.

Experiments with Geissler tubes are of special interest. An exhausted tube, devoid of electrodes of any kind, will light up at some distance from the coil. If a tube from a vacuum pump is near the coil, the whole of the pump is brilliantly lighted. An incandescent lamp approached to the coil lights up and gets perceptibly hot. If a lamp have the terminals connected to one of the binding posts of the coil and the hand is approached to the bulb, a very curious and rather unpleasant discharge from the glass to the hand takes place, and the filament may become incandescent. The discharge resembles to some extent the stream issuing from the plates of a powerful Toepler machine, but is of incomparably greater quantity. The lamp in this case acts as a condenser, the rarefied gas being one coating, the operator's hand the other. By taking the globe of a lamp in the hand, and by bringing the metallic terminals near to or in contact with a conductor connected to the coil, the carbon is brought to bright incandescence and the glass is rapidly heated. With a 100-volt 10 c. p. lamp one may without great discomfort stand as much current as will bring the lamp to a considerable brilliancy; but it can be held in the hand only for a few minutes, as the glass is heated in an incredibly short time. When a tube is lighted by bringing it near to the coil, it may be made to go out by interposing a metal plate or the hand between the coil and tube; but if the metal plate be fastened to a glass rod or otherwise insulated, the tube may remain lighted if the plate be interposed, or may even increase in luminosity. The effect depends on the position of the plate and tube relatively to the coil, and may be always easily foretold by *assuming* that conduction takes place from one terminal of the coil to the other. According to the position of the plate, it may either divert from or direct the current to the tube.

In another line of work the writer has in frequent experiments maintained incandescent lamps of 50 or 100 volts, burning at any desired candle power, with both the terminals of each lamp connected to a stout copper wire of no more than a few feet in length. These experiments seem interesting enough, but they are not more so than the queer experiment of Faraday, which has been revived and made much of by recent investigators, and in which a discharge is made to jump between two points of a bent copper wire. An experiment may be cited here which may seem equally interesting. If a Geissler tube, the terminals of which are joined by a copper wire, be approached to the coil, certainly no one would be prepared to see the tube light up. Curiously enough, it does light up, and, what is more, the wire does not seem to make much difference. Now one is apt to think in the first moment that the impedence of the wire might have something to do with the phenomenon. But this is of course immediately rejected, as for this an enormous frequency would be required. The result, however, seems puzzling only at first; for upon reflection it is quite clear that the wire can make but little difference. It may be explained in more than one way, but it agrees perhaps best with observation to assume that conduction takes place from the terminals of the coil through the space. On this assumption, if the tube with the wire be held in any position, the wire can divert little more than the current which passes through the space occupied by the wire and the metallic terminals of the tube; through the adjacent space the current passes practically undisturbed. For this reason, if the tube be held in any position at right angles to the line joining the binding posts of the coil, the wire makes hardly any difference, but in a position more or less parallel with that line it impairs to a certain extent the brilliancy of the tube and its facility to light up. Numerous other phenomena may be explained on the same assumption. For instance, if the ends of the tube be provided with washers of sufficient size and held in the line joining the terminals of the coil, it will not light up, as then nearly the whole of the current, which would otherwise pass uniformly through the space between the washers, is diverted through the wire. But if the tube be inclined sufficiently to that line, it will light up in spite of the washers. Also, if a metal plate be fastened upon a glass rod and held at right angles to the line joining the binding posts, and nearer to one of them, a tube held more or less parallel with the line will light up instantly when one of its terminals touches the plate and will go out when separated from the plate. The greater the surface of the plate up to a certain limit, the easier the tube will light up. When a tube is placed at right angles to the straight line joining the binding posts, and then rotated, its luminosity steadily increases until it is parallel with that line. The writer must state, however, that he does not favor the idea of a leakage or current through the space any more than as a suitable explanation, for he is convinced that all these experiments could not be performed with a static machine yielding a constant difference of potential, and that condenser action is largely concerned in these phenomena.

It is well to take certain precautions when operating a Ruhmkorff coil with very rapidly alternating currents. The primary current should not be turned on too long, else the core may get so hot as to melt the gutta-percha or paraffin, or otherwise injure the insulation, and this may occur in a surprisingly short time, the current's strength considered. The primary current being turned on, the fine wire terminals may be joined without great risk, the impedence being so great that it is difficult to force enough current through the fine wire so as to injure it, and in fact the coil may be on the whole much safer when the terminals of the fine wire are connected than when they are insulated; but special care should be taken when the terminals are connected to the coatings of a Leyden jar, for with anywhere near the critical capacity, which just counteracts the self-induction at the existing frequency, the coil might meet the fate of St. Polycarpus. If an expensive vacuum pump is lighted up by being near to the coil or touched with a wire connected to one of the terminals, the current should be left on no more than a few moments, else the glass will be cracked by the heating of the rarefied gas in one of the narrow passages—in the writer's own experience *quod erat demonstrandum*.*

There are a good many other points of interest which may be observed in connection with such a machine. Experiments with the telephone, a conductor in a strong field or with a condenser or arc seem to afford certain proof that sounds far above the usual accepted limit of hearing would be perceived. A telephone will emit notes of twelve to thirteen thousand vibrations per second, then the inability of the core to follow such rapid alternations begins to tell. If, however, the magnet and core be replaced by a condenser and the terminals connected to the high-tension secondary of a transformer, higher notes may still be heard. If the current be sent around a finely laminated core and a small piece of thin sheet iron be held gently against the core, a sound may be still heard with thirteen to fourteen thousand alternations per second, provided the current is sufficiently strong. A small coil, however, tightly packed between the poles of a powerful magnet, will emit a sound with the above number of alternations, and arcs may be audible with still a higher frequency. The limit of audition is variously estimated. In Sir William Thomson's writings it is stated somewhere that ten thousand per second, or nearly so, is the limit. Other, but less reliable, sources give it as high as twenty-four thousand per second. The above experiments have convinced the writer that notes of an incomparably higher number of vibrations per second would be perceived, provided they could be produced with sufficient power. There is no reason why it should not be so. The condensations and rarefactions of the air would necessarily set the diaphragm in a corresponding vibration, and some sensation would be produced whatever—within certain limits—the velocity of transmission to their nerve centers, though it is probable that for want of exercise the ear would not be able to distinguish any such high note. With the eye it is different; if the sense of vision is based upon some resonance effect, as many believe, no amount of increase in the intensity of the ethereal vibration could extend our range of vision on either side of the visible spectrum.

The limit of audition of an arc depends on its size. The greater the surface by a given heating effect in the arc, the higher the limit of audition. The highest notes are emitted by the high-tension discharges of an induction coil in which the arc is, so to speak, all surface. If R be the resistance of an arc, and C the current, and the linear dimensions be n times increased, then the resistance is $\frac{R}{n}$, and with the same current density the current would be n^2C; hence the heating effect is n^3 times greater, while the surface is only n^2 times as great. For this reason very large arcs would not emit any rhythmical sound even with a very low frequency. It must be observed, however, that the sound emitted depends to some extent also on the composition of the carbon. If the carbon contain highly refractory material, this when heated tends to maintain the temperature of the arc uniform, and the sound is lessened; for this reason it would seem that an alternating arc requires such carbons.

With currents of such high frequencies it is possible to obtain noiseless arcs, but the regulation of the lamp is rendered extremely difficult on account of the excessively small attractions or repulsions between conductors conveying these currents.

An interesting feature of the arc produced by these rapidly alternating currents is its persistency. There are two causes for it, one of which is always present, the other sometimes only. One is due to the character of the current, and the other to a property of the machine. The first cause is the more important one, and is due directly to the rapidity of the alternations. When an arc is formed by a periodically undulating current, there is a corresponding undulation in the temperature of the gaseous column, and, therefore, a corresponding undulation in the resistance of the arc. But the resistance of the arc varies enormously with the temperature of the gaseous column, being practically infinite when the gas between the electrodes is cold. The persistence of the arc, therefore, depends on the inability of the column to cool. It is for this reason impossible to maintain an arc with the current alternating only a few times a second. On the other hand, with a practically continuous current, the arc is easily maintained, the column being constantly kept at a high temperature and low resistance. The higher the frequency, the smaller the time interval during which the arc may cool and increase considerably in resistance. With a frequency of 10,000 per second or more in an arc of same size, excessively small variations of temperature are superimposed upon a steady temperature, like ripples on the surface of a deep sea. The heating effect is practically continuous and the arc behaves like one produced by a continuous current, with the exception, however, that it may not be quite as easily started, and that the electrodes are equally consumed; though the writer has observed some irregularities in this respect.

The second cause alluded to, which possibly may not be present, is due to the tendency of a machine of such high frequency to maintain a practically constant current. When the arc is lengthened the electromotive force rises in proportion, and the arc appears to be more persistent.

Such a machine is eminently adapted to maintain a constant current, but it is very unfit for a constant potential. As a matter of fact, in certain types of such machines a nearly constant current is an almost unavoidable result. As the number of poles or polar projections is greatly increased, the clearance becomes of great importance. One has really to do with a great number of very small machines. Then there is the impedence in the armature, enormously augmented by the high frequency. Then, again, the magnetic leakage is facilitated. If there are three or four hundred alternate poles, the leakage is so great that it is virtually the same as connecting, in a two-pole machine, the

* It is thought necessary to remark that, although the induction coil may give quite a good result when operated with such rapidly alternating currents, yet its construction, quite irrespective of the iron core, makes it very unfit for such high frequencies, and to obtain the best results the construction should be greatly modified.

poles by a piece of iron. This disadvantage, it is true, may be obviated more or less by using a field throughout of the same polarity, but then one encounters difficulties of a different nature. All these things tend to maintain a constant current in the armature circuit.

In this connection it is interesting to notice that even to day engineers are astonished at the performance of a constant current machine, just as, some years ago, they used to consider it an extraordinary performance if a machine was capable of maintaining a constant potential difference between the terminals. Yet one result is just as easily secured as the other. It must only be remembered that in an inductive apparatus of any kind, if constant potential is required, the inductive relation between the primary or exciting and secondary or armature circuit must be the closest possible; whereas, in an apparatus for constant current just the opposite is required. Furthermore, the opposition to the current's flow in the induced circuit must be as small as possible in the former and as great as possible in the latter case. But opposition to a current's flow may be caused in more than one way. It may be caused by ohmic resistance or self-induction. One may make the induced circuit of a dynamo machine or transformer of such high resistance that when operating devices of considerably smaller resistance within very wide limits a nearly constant current is maintained. But such high resistance involves a great loss in power, hence it is not practicable. Not so self-induction. Self-induction does not necessarily mean loss of power. The moral is, use self-induction instead of resistance. There is, however, a circumstance which favors the adoption of this plan, and this is that a very high self-induction may be obtained cheaply by surrounding a comparatively small length of wire more or less completely with iron, and, furthermore, the effect may be exalted at will by causing a rapid undulation of the current. To sum up, the requirements for constant current are: Weak magnetic connection between the induced and inducing circuits, greatest possible self-induction with the least resistance, greatest practicable rate of change of the current. Constant potential, on the other hand, requires: Closest magnetic connection between the circuits, steady induced current, and, if possible, no reaction. If the latter conditions could be fully satisfied in a constant potential machine, its output would surpass many times that of a machine primarily designed to give constant current. Unfortunately, the type of machine in which these conditions may be satisfied is of little practical value, owing to the small electromotive force obtainable, and the difficulties in taking off the current.

With their keen inventor's instinct, the now successful arc light men have early recognized the desiderata of a constant current machine. Their arc light machines have weak fields, large armatures, with a great length of copper wire and a few commutator segments to produce great variations in the current's strength, and to bring self-induction into play. Such machines may retain within considerable limits of variation in the resistance of the circuit a practically constant current. Their output is, of course, correspondingly diminished, and, perhaps, with the object in view not to cut down the output too much, a simple device compensating exceptional variations is employed. The undulation of the current is almost essential to the commercial success of an arc light system. It introduces in the circuit a steadying element, taking the place of a large ohmic resistance, without involving a great loss in power, and, what is more important, it allows the use of simple clutch lamps, which with a current of a certain number of impulses per second, best suitable for each particular lamp, will, if properly attended to, regulate even better than the finest clockwork lamps. This discovery has been made by the writer—several years too late.

It has been asserted by competent English electricians that in a constant current machine or transformer the regulation is effected by varying the phase of the secondary current. That this view is erroneous may be easily proved by using, instead of lamps devices each possessing self-induction and capacity or self-induction and resistance—that is, retarding and accelerating components—in such proportions as to not affect materially the phase of the secondary current. Any number of such devices may be inserted or cut out, still it will be found that the regulation occurs, a constant current being maintained, while the electromotive force is varied with the number of the devices. The change of phase of the secondary current is simply a result following from the changes in resistance, and, though secondary reaction is always of more or less importance, yet the real cause of the regulation lies in the existence of the conditions above enumerated. It should be stated, however, that in the case of a machine the above remarks are to be restricted to the cases in which the machine is independently excited. If the excitation be effected by commutating the armature current, then the fixed position of the brushes makes any shifting of the neutral line of the utmost importance, and it may not be thought immodest of the writer to mention that, as far as records go, he seems to have been the first who has successfully regulated machines in providing a bridge connection between a point of the external circuit and the commutator by means of a third brush. The armature and field being properly proportioned, and the brushes placed in their determined positions, a constant current or constant potential resulted from the shifting of the diameter of commutation by the varying loads.

In connection with machines of such high frequencies the condenser affords an especially interesting study. It is easy to raise the electromotive force of such a machine to four or five times the value by simply connecting the condenser to the circuit, and the writer has continually used the condenser for the purposes of regulation as suggested by Blakesley in his book on alternate currents, in which he has treated the most frequently occurring condenser problems with exquisite simplicity and clearness. The high frequency allows the use of small capacities and renders investigation easy. But, although in most of the experiments the result may be foretold, yet some phenomena observed seem at first curious. One experiment performed three or four months ago with such a machine and a condenser may serve as an illustration. A machine was used giving about 20,000 alternations per second. Two bare wires of about 20 feet long and two millimeters diameter, in close proximity to each other, were connected to the terminals of the machine on the one end, and to a condenser on the other. A small transformer without an iron core, of course, was used to bring the reading within the range of a Cardew voltmeter by connecting the voltmeter to the secondary. On the terminals of the condenser the electromotive force was about 120 volts, and from there inch by inch it gradually fell until on the terminals of the machine it was about 65 volts. It was virtually as though the condenser were a generator, and the line and armature circuit simply a resistance connected to it. The writer looked for a case of resonance, but he was unable to augment the effect by varying the capacity very carefully and gradually or by changing the speed of the machine. A case of pure resonance he was unable to obtain. When a condenser was connected to the terminals of the machine—the self-induction of the armature being first determined in the maximum and minimum position and the mean value taken—the capacity which gave the highest electromotive force corresponded most nearly to that which just counteracted the self-induction with the existing frequency. If the capacity was increased or diminished, the electromotive force fell as expected.

With frequencies as high as the above mentioned the condenser effects are of enormous importance. The condenser becomes a highly efficient apparatus, capable of transferring considerable energy.

The writer has thought that machines of high frequencies may find use at least in cases when transmission at great distances is not contemplated. The increase of the resistance may be reduced in the conductors and exalted in the devices when heating effects are wanted, transformers may be made of higher efficiency, and greater outputs and valuable results may be secured by means of condensers. In using machines of high frequency the writer has been able to observe condenser effects which would have otherwise escaped his notice. He has been very much interested in the phenomenon observed on the Ferranti main which has has been so much spoken of. Opinions have been expressed by competent electricians, but up to the present all still seems to be conjecture. Undoubtedly in the views expressed the truth must be contained, but as the questions differ, some must be erroneous. Upon seeing the diagram of M. Ferranti in the *Electrician* of Dec. 19 the writer has formed his opinion of the effect. In the absence of all the necessary data he must content himself to express in words the process which, in his opinion, must undoubtedly occur. The condenser brings about two effects: (1) It changes the phases of the currents in the branches; (2) it changes the strength of the currents. As regards the change in phase, the effect of the condenser is to accelerate the current in the secondary at Deptford and to retard it in the primary at London. The former has the effect of diminishing the self-induction in the Deptford primary, and this means lower electromotive force on the dynamo. The retardation of the primary at London, as far as merely the phase is concerned, has little or no effect, since the phase of the current in the secondary in London is not arbitrarily kept.

Now, the second effect of the condenser is to increase the current in both the branches. It is immaterial whether there is equality between the currents or not; but it is necessary to point out, in order to see the importance of the Deptford step-up transformer, that an increase of the current in both the branches produces opposite effects. At Deptford it means further lowering of the electromotive force at the primary, and at London it means increase of the electromotive force at the secondary. Therefore all the things co-act to bring about the phenomenon observed. Such actions, at least, have been found to take place under similar conditions. When the dynamo is connected directly to the main, one can see that no such action can happen.

The writer has been particularly interested in the suggestions and views expressed by Mr. Swinburne. Mr. Swinburne has frequently honored him by disagreeing with his views. Three years ago, when the writer, against the prevailing opinion of engineers, advanced an open circuit transformer, Mr. Swinburne was the first to condemn it by stating in the *Electrician*: "The (Tesla) transformer must be inefficient; it has magnetic poles revolving, and has thus an *open* magnetic circuit." Two years later Mr. Swinburne becomes the champion of the open circuit transformer, and offers to convert him. But, *tempora mutantur et nos mutamur in illis*.

The writer cannot believe in the armature reaction theory as expressed in *Industries*, though undoubtedly there is some truth in it. Mr. Swinburne's interpretation, however, is so broad that it may mean anything.

Mr Swinburne seems to have been the first who has called attention to the heating of the condensers. The astonishment expressed at that by the ablest electrician is a striking illustration of the desirability to execute experiments on a large scale. To the scientific investigator, who deals with the minutest quantities, who observes the faintest effects, far more credit is due than to one who experiments with apparatus on an industrial scale, and indeed the history of science has recorded examples of marvelous skill, patience and keenness of observation. But however great the skill, and however keen the observer's perception, it can only be of advantage to magnify an effect and thus facilitate its study. Had Faraday carried out but one of his experiments on dynamic induction on a large scale, it would have resulted in an incalculable benefit.

In the opinion of the writer, the heating of the condensers is due to three distinct causes: first, leakage or conduction; second, imperfect elasticity in the dielectric; and third, surging of the charges in the conductor.

In many experiments he has been confronted with the problem of transferring the greatest possible amount of energy across a dielectric. For instance, he has made incandescent lamps, the ends of the filaments being completely sealed in glass, but attached to interior condenser coatings, so that all the energy required had to be transferred across the glass with a condenser surface of no more than a few centimeters square. Such lamps would be a practical success with sufficiently high frequencies. With alternations as high as 15,000 per second it was easy to bring the filaments to incandescence. With lower frequencies this could also be effected, but the potential difference had, of course, to be increased. The writer has then found that the glass gets, after a while, perforated and the vacuum is impaired. The higher the frequency, the longer the lamp can withstand. Such a deterioration of the dielectric always takes place when the amount of energy transferred across a dielectric of definite dimensions and by a given frequency is too great. Glass withstands best, but even glass is deteriorated. In this case the potential difference on the plates is of course too great, and losses by conduction and imperfect elasticity result. If it is desirable to produce condensers capable to stand great differences of potential, then the only dielectric which will involve no losses is a gas under pressure. The writer has worked with air under enormous pressures, but there are a great many practical difficulties in that direction. He thinks that, in order to make the condensers of considerable practical utility, higher frequencies should be used; though such a plan has, besides others, the great disadvantage that the system would become very unfit for the operation of motors.

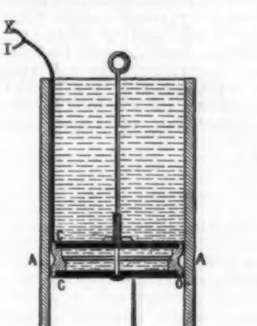
If the writer does not err, Mr. Swinburne has suggested a way of exciting an alternater by means of a condenser.

For a number of years past the writer has carried on experiments with the object in view of producing a practical self-exciting alternater. He has in a variety of ways succeeded in producing some excitation of the magnets by means of alternating currents, which were not commutated by mechanical devices. Nevertheless his experiments have revealed a fact which stands as solid as the rock of Gibraltar. No practical excitation can be obtained with a single periodically varying and not commutated current. The reason is that the changes in the strength of the exciting current produce corresponding changes in the field strength, with the result of inducing currents in the armature, and these currents interfere with those produced by the motion of the armature through the field, the former being a quarter phase in advance of the latter. If the field be laminated, no excitation can be produced; if it be not laminated, some excitation is produced, but the magnets are heated.

By combining two exciting currents displaced by a quarter phase, excitation may be produced in both cases, and if the magnet be not laminated the heating effect is comparatively small, as a uniformity in the field strength is maintained, and, were it possible to produce a perfectly uniform field, excitation on this plan would give quite practical results. If such results are to be secured by the use of a condenser, as suggested by Mr. Swinburne, it is necessary to combine two circuits separated by a quarter phase; that is to say, the armature coils must be wound in two sets and connected to one or two independent condensers. The writer has done some work in that direction, but must defer the description of the devices for some future time.

URQUHART'S BATTERY.

A SIMPLE cell, from which a current of great strength may be obtained for a short time, may be constructed by employing two plates of carbon and one of amalgamated zinc placed between them. The three plates are usually attached to a beam of wood, and so insulated. The two carbon plates are connected together as one by a brass clamp. This combination is excited by a solution of bichromate of potash acidulated by 2 oz. (to each pint) of sulphuric acid. The resulting action is exceedingly vigo[rous], but it is not maintained unless the plates be disturbed so as to cause circulation of the liquid.



URQUHART'S BATTERY.

Various attempts have been made to cause the solution to circulate of itself, and so prolong the action of the cell. One of the best of these is the sustaining battery devised by Mr. J. W. Urquhart. It consists of an arrangement by means of which gravity causes the exciting liquid to continue in motion until it is exhausted. The engraving represents an element made according to this device. The containing vessel is cylindrical and deep. The plates are two disks of carbon and one of zinc, placed in a horizontal plane, in a wooden case fitting the containing vessel in the manner of an air-tight piston. The piston is packed by means of a rubber ring, stretched in a groove turned in the face, as represented in section. The carbon plates may be connected together by means of a metallic stem, which is free of the zinc by an aperture cut in the center. This metallic stem must be of platinum. Ivory or ebonite may be used, and the connection may thus be made between the carbon plates, and to the exterior conductor, by means of a piece of platinum wire in the wooden annular frame. The connection with the zinc is made by means of a plug and taper tube of platinum, with a gutta-percha-covered wire leading out of the cell. By these means the zinc plate may be replaced by a fresh disk when worn without trouble. No soldering is necessary at any part of the element. The lifting stem may either be of two parts, so as to divide, or it may be made to act as a nut to screw down upon the car-

bon plate. The exciting liquid is poured into the upper half of the containing vessel, and flows into the element through an aperture in the upper carbon. A still smaller aperture is provided through the lower carbon plate, and the liquid thus slowly percolates through the cell, falling into the lower compartment drop by drop. A small air outlet is provided at the upper end of the lower compartment. By these means the action of the cell may be continued, in full even flow of current, as long as any of the exciting liquid remains in the upper compartment. It is thus possible and easy to obtain from the bichromate cell more favorable results than from the Bunsen generator. The force is greater, there is no fume, the resistance is much less, and the constancy is superior. A cell of the above type may be made to continue in action for days together, and supply its full force throughout that time. When the lower compartment is full, and the solution be deemed still strong enough, the element may be slowly depressed. This will force the lower liquid up through the element into the upper compartment once more.

One of the great advantages of this type of element is its extremely low internal resistance, which is often not more than 0·1 ohm. The plates may be placed very closely together, compatible with allowing due circulation of the excitant. The zinc plate should in all cases be carefully amalgamated. The current yielded is frequently as great as that from two Bunsen cells of equal size.

POWERFUL PLUNGE BATTERY

THE plunging battery shown in Fig. 1 is a very powerful one, designed for running an electric motor or for supplying a current to three or four small incandescent lamps. The battery consists of eight elements, each formed of two 6 × 10 inch carbon plates ¼ inch thick, and one zinc plate of the same size, suspended in a cell 3¼ × 7½ inches and 9 inches deep.

The upper ends of the carbon plates are paraffined, as shown in Fig. 2, by heating the ends only and rubbing on paraffine, allowing it to melt and soak into the pores of the plate until a strip about 1½ inches wide across the end of the plate is well filled with paraffine. This treatment prevents the solution from ascending by capillarity and destroying the connections.

The plates are arranged as shown in Fig. 3, the zinc plate being located between two carbon plates and separated from them by strips of paraffined wood ¼

FIG. 1.—LARGE PLUNGE BATTERY.

inch thick, 1¼ inches wide, and 8 inches long. The plates and separating strips are clamped together by thick strips of paraffined wood arranged upon the outer side of the carbon plates, and bolts, preferably of brass, passing through the ends of all of the strips. The electrical connection with the zinc plate is made by inserting a copper strip, *a*, between the plate and the wood strip. The connection with the carbon plates is made in a similar way, the strip, *b*, being looped so as to form a contact with both plates without touching the zinc.

Before the elements are put together, the zinc plates should be carefully amalgamated. This is done by dipping each plate into a jar of dilute sulphuric acid (acid 1 part, water 10 parts), containing mercury at the bottom. As soon as the lower end of the plate is coated with mercury it may be lifted from the solution, inverted and allowed to stand until the entire surface of the plate is perfectly covered with mercury. If there are portions which do not receive the mercury, they are scraped or sand-papered and returned to the acid solution, when mercury is applied locally.

If the amalgamation is perfect, the plates will not require re-amalgamation. An amalgamating solution is

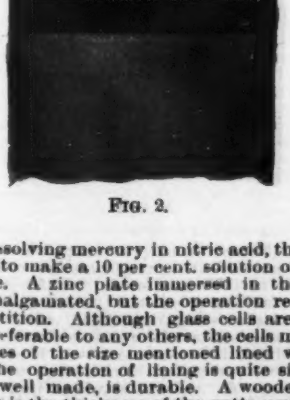


FIG. 2.

made by dissolving mercury in nitric acid, then adding water so as to make a 10 per cent. solution of the mercury nitrate. A zinc plate immersed in the solution becomes amalgamated, but the operation requires frequent repetition. Although glass cells are on many accounts preferable to any others, the cells may consist of pine boxes of the size mentioned lined with gutta percha. The operation of lining is quite simple, and the cell, if well made, is durable. A wooden form is made which is the thickness of the gutta percha smaller than the boxes. Around the sides and end of this form is wrapped a sheet of gutta percha, which is ¾ inch wider than the form, the edges of the sheet being allowed to project beyond the form, as shown in Fig. 4.

A piece of gutta percha of suitable width and length is placed upon the form within the projecting edges of the sheet already in position. The edges are then warmed sufficiently to render them adhesive, by

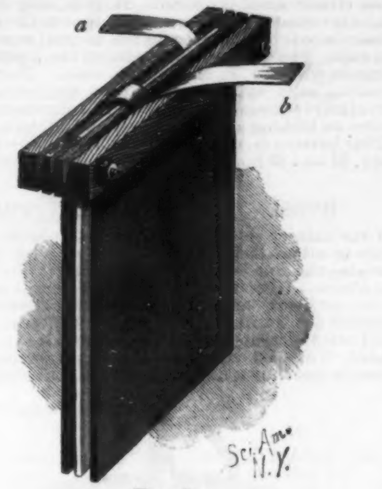


FIG. 3.

means of a lamp flame or by holding a hot iron near enough to soften the gutta percha. The edge is then turned over in the manner illustrated. The fingers should be moistened to prevent the gutta percha from adhering to them. When the lining is complete, it is placed in the wooden box and expanded to fit by filling it with warm water. The upper edges of the lining should be turned over upon the edge of the box and made to adhere by heating. The box should be thoroughly coated with shellac varnish inside and outside, and allowed to dry before introducing the lining. Eight of these cells are placed in a box having removable sides and a frame extending over the top. To the vertical standard of the frame is loosely fitted a horizontal frame which supports the plates of the battery. In the upper part of the frame is journaled a shaft provided at opposite ends with drums, to which are attached chains for lifting the horizontal frame and plates supported thereby. The shaft is provided with a crank by which it may be turned, and with a ratchet which is engaged by a spring pawl attached to one of the standards.

The copper strips connected with the zinc plates are clamped to the strips extending from the carbon plates, and the terminal strips are provided with binding posts for receiving conductors. Each set of plates is provided with a hook, attached to the clamping strips by means of a cross bar of vulcanite or vulcanized fiber. These hooks are designed to be placed on the shaft when it is desired to use only a part of the cells, the unused plates being detached from the others and

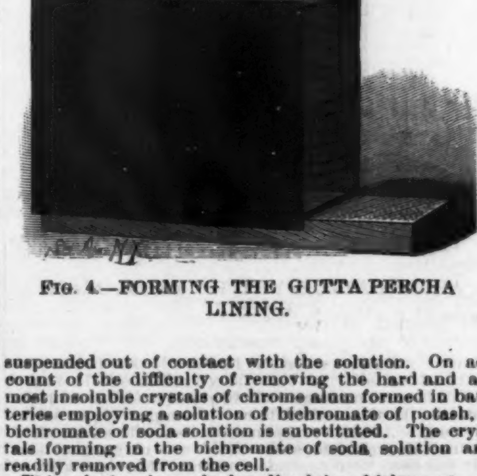


FIG. 4.—FORMING THE GUTTA PERCHA LINING.

suspended out of contact with the solution. On account of the difficulty of removing the hard and almost insoluble crystals of chrome alum formed in batteries employing a solution of bichromate of potash, a bichromate of soda solution is substituted. The crystals forming in the bichromate of soda solution are readily removed from the cell.

This solution is made by dissolving bichromate of soda in warm water to saturation, allowing it to cool, then slowly adding commercial sulphuric acid to the amount of one-fifth of the volume of the bichromate solution. As the gutta percha lining of the cells melts at a low temperature, the solution should be allowed to cool before pouring it into the cells.

The plates should not be plunged into the solution to a greater depth than is necessary for the production of the desired current, and they should always be withdrawn immediately after use. The electro-motive force of this battery is 16·0 volts, and the maximum current is about 4 amperes.

THE EDISON-LALANDE BATTERY.

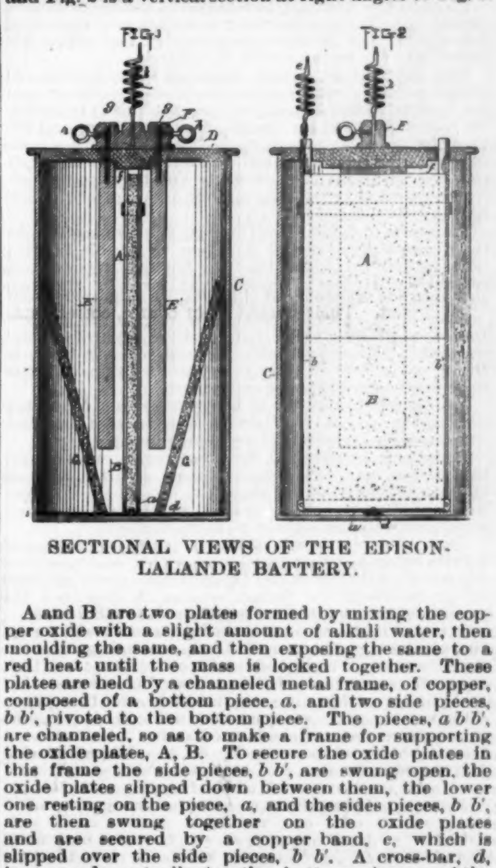
THE Edison-Lalande cell is a modification, or rather a development of the battery invented some years ago by Messrs. De Lalande and Chaperon. The Lalande-Chaperon cell attracted considerable attention at the time of its appearance on account of its comparative simplicity and other advantages, principal among which were its low internal resistance and constancy of action. The battery, however, was of a somewhat cumbersome description, the outer cell being of cast iron, having an ebonite cover from which was suspended the zinc element coiled in spiral shape. The bottom of the outer cell, which constituted the negative electrode, was covered with copper oxide, on top of which was poured a solution of caustic potash. The cover was hermetically sealed by means of flanges and nuts.

Edison's patent specification describes this battery as follows:

In carrying out my invention I mould the copper oxide into plates by mixing the copper oxide with a slight amount of alkali water—say soda—and then hardening the plates by exposing them to a red heat until the mass is well locked together. The plates of copper oxide thus formed are clamped between copper plates, which form a frame supporting the edges of the oxide plates and holding them together.

The construction of the negative electrode of the battery is the principal feature of the invention; but the invention also consists in other matters of detail, which will presently appear.

In the accompanying drawings, forming a part hereof, Fig. 1 is a vertical section of a cell of the battery, and Fig. 2 is a vertical section at right angles to Fig. 1.



SECTIONAL VIEWS OF THE EDISON-LALANDE BATTERY.

A and B are two plates formed by mixing the copper oxide with a slight amount of alkali water, then moulding the same, and then exposing the same to a red heat until the mass is locked together. These plates are held by a channeled metal frame, of copper, composed of a bottom piece, *a*, and two side pieces, *b b'*, pivoted to the bottom piece. The pieces, *a b b'*, are channeled, so as to make a frame for supporting the oxide plates, A, B. To secure the oxide plates in this frame the side pieces, *b b'*, are swung open, the oxide plates slipped down between them, the lower one resting on the piece, *a*, and the sides pieces, *b b'*, are then swung together on the oxide plates and are secured by a copper band, *c*, which is slipped over the side pieces, *b b'*. A cross-bar, *d*, is secured centrally to the bottom piece, *a*, of the frame, so as to insure the central position of the negative electrode in the glass jar, C. The top of the glass jar is closed by a cover, D, made, preferably, of porcelain and having openings through which the upper ends of the side pieces, *b b'*, project. A connecting wire, *e*, is secured to one of the projecting ends of the side pieces. The cover, D, is moulded with a central rib, *f*, extending transversely part way across it. Two zinc plates, E E', are supported from the under side of the cover, D, on opposite sides of the rib, *f*. Metal pins, *g*, from the zinc plates pass upwardly through the cover, D, and enter a metal block, F, in which they are secured by set screws, *h*. A wire, *i*, for making circuit connections may be secured to the block, F. The rib, *f*, maintains the zinc plates, E E', a definite distance apart, and between the two zinc plates is located the negative electrode formed of the copper oxide plates, A B, and the sustaining frame. This construction produces an exceedingly simple and compact form of the battery and one which can be conveniently renewed, since the copper oxide plates can be readily replaced. I preferably employ two copper oxide plates instead of one, for convenience in moulding, and so that the upper plate can be reversed in renewing the plates, so as to immerse that part of the plate which before was above the liquid. A single plate, however, can be employed.

The solution employed is preferably a twenty-five per cent. solution of caustic soda; but other caustic alkali—such as caustic potash—may be employed. To obtain this I employ sticks, G, Fig. 1, of caustic soda, which are formed by melting the soda and running it into moulds. The glass is filled with water and the

soda sticks put in. These being made of the material fused into a solid mass, they dissolve slowly, and the glass jar is saved from injury. If the caustic soda were put into the glass jar in the form of powder, the heat produced by its rapid dissolution would be liable to crack the jar.

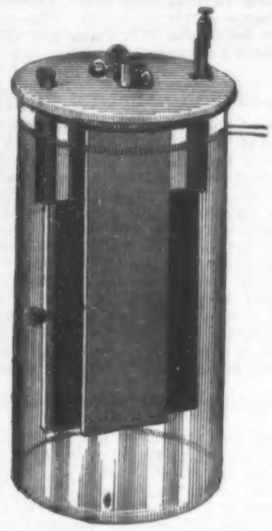


FIG. 3.—EDISON-LALANDE CELL, TYPE K.

These cells are made in eight different types to adapt them to different uses. This battery is applied to telegraphy, telephony, household and motor work, plating, cautery, etc.

The following directions are given for setting up the Edison-Lalande battery:

Place in the jar half the required charge of caustic potash and fill up with water to within one inch from top of jar. Stir solution occasionally, and when dissolved add the remainder of the charge.

The solution of potash sticks in water is attended with a considerable rise of temperature, especially near the bottom of the jar, and on this account it is advisable to dissolve half the charge of potash first, and stir the solution occasionally, while dissolving, with a piece of wood. This insures a uniform temperature throughout the solution and prevents any breakage of jar. The balance of the potash may be added after the first half is nearly dissolved.

Pass ends of both zincs through the two small holes near center of cover and fit them in double binding post, in such a position that the hooks at top of zincs rest on the flat top of binding post and the zincs are suspended therefrom. Tighten up set screws.

Place copper plate in frame, the slotted end at bottom, into which fit the hard rubber separator point upward. Pass copper bolt through oblong holes in frame, and screw on thumb nut so that sides of frame may press against copper oxide plate.

Pour a small quantity of heavy paraffine oil on top of solution so as to form a layer of oil about one-quarter inch deep on surface to keep out the air.

If battery is required to give strong current (for motor work, etc.) it is better to short circuit, *i. e.*, close the battery on itself for about ten to fifteen minutes, but care must be taken not to do so longer than necessary, or it will cause great waste in battery.

After potash is dissolved it may be necessary to add a little water to bring solution to within one inch from top of cell, when zincs and copper frame are in position on jar, as when the potash charge is dissolved the volume of solution will be found to have diminished.

It is most important that oxide plates should be entirely submerged in caustic potash solution, so that the top edges of oxide plates should be at least one inch below the layer of oil. It is of vital importance that the oil above referred to should not be omitted. When oil is not used, creeping salts are formed, and the life of the cell is reduced fully two-thirds.

This battery is made by the Edison Manufacturing Co., Orange, N. J.

BISULPHATE OF MERCURY CELL.

IN Hussey's patent bisulphate of mercury battery the improvement consists in using the bisulphate of

BISULPHATE OF MERCURY BATTERY.

mercury in such a manner that this will not polarize, the bisulphate being packed in the porous cell around the carbon. This battery, which is known as the Eclipse battery, is intended for closed circuit work, and will not polarize. It can be left on open circuit for any length of time and yet when wanted will be ready for use. Water only is used in charging this battery, all the chemicals necessary being contained in the porous cup, which is sealed. The Eclipse battery has no fumes or odor and is simple and clean. It can be used for open circuit work if desired. It is an easy battery to take care of, as it requires no attention until exhausted, when there is nothing to do but to put in a new porous cup. The battery, it is said, gives a current of 5 amperes with an E. M. F. of 1½ volts. There are no climbing salts and no bad carbon connections. The zinc always remains clear and well amalgamated and requires no looking after except renewal when consumed.

This battery is made by the Crosby Electric Company, 87 and 89 South Fifth Avenue, New York.

HUSSEY BLUESTONE BATTERY.

THIS battery resembles the Daniell in some respects, while in others it is like the gravity. The cell which contains the zinc is non-porous at the bottom and porous above. It rests upon the copper, and the space in the jar below and around the lower part of the cell contains the sulphate of copper. The porous cell is filled with acidulated water and the zinc is amalgamated. The battery is provided with a porcelain cover, which is not shown in the engraving. Among the uses

THE HUSSEY BLUESTONE BATTERY.

to which this battery is applied are telegraphy, telephony, running small motors, charging secondary batteries, operating small incandescent lamps, etc. The Crosby Electric Co., 87 South Fifth Ave., New York, are manufacturers of this battery.

GASSNER'S DRY BATTERY.

DR. CARL GASSNER'S patent dry battery is much the same in principle as the Leclanche, but the exciting fluid is contained in a paste, and the zinc element forms the containing vessel. Two forms of the battery are made, one being cylindrical, as shown in Fig. 1, the other elliptical, as shown in Fig. 2.

The carbon rod or plate occupies about one-half of the space in the cell, and the space between the carbon and the cell is filled with the following mixture:

"Oxide of zinc, 1 part, by weight; sal ammoniac, 1 part, by weight; plaster, 3 parts, by weight; chloride of zinc, 1 part, by weight; water, 2 parts, by weight. The oxide of zinc in this composition loosens and makes

FIG. 1. FIG. 2.

DR. GASSNER'S DRY BATTERY.

it porous, and the greater porosity thus obtained facilitates the interchange of the gases and diminishes the tendency to the polarization of the electrodes."

The battery works well on an open circuit, and is cleanly and portable.

This battery illustrates the general form of nearly all dry batteries. The mixture used in the cell differs somewhat with different manufacturers.

LALANDE-CHAPERON CELL.

THE caustic potash battery represented in two forms in Figs. 1 and 2 is of comparatively recent invention. It is adapted to either open or closed circuit work, and will operate for several months without replenishing. It has been used successfully in electroplating and in electric lighting on a small scale.

The cell is made of cast iron and serves as one of the plates of the battery. It is much heavier than a glass cell, but this is compensated for by its non-liability to breakage.

In the small pattern the iron cell, V, is closed by a rubber stopper, G, through which passes a brass rod, K, provided at its upper end with a binding post, F, and carrying at its lower end the zinc cylinder, D. A

FIG. 1.

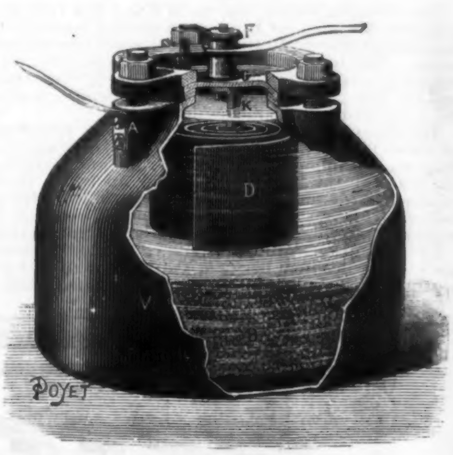


FIG. 2.

CAUSTIC POTASH BATTERY.

lug, A, on the cell is provided with a binding screw for clamping the conductor, C. The cell is filled with a saturated solution of caustic potash, and upon the bottom of the cell is distributed a quantity of black oxide of copper.

A valve, H, formed of a piece of rubber tubing, is inserted in the stopper to admit of the escape of gas.

The large pattern shown in Fig. 2 is 9 inches in diameter. It is similar in its construction to the smaller cell. The zinc element in this case is formed of a plate bent spirally. It is not necessary to amalgamate the zincs in this battery. It is stated that the small cell yields a current of 2 amperes, while the larger one is capable of yielding 8 amperes. The E. M. F. is one volt.

THE GIANT ANT-EATER.

AMONG the mammals of the present fauna there exist certain types which, by their strange aspect, or their unusual proportions, offer a contrast with the generally modest forms that surround us, and which are comparable with those sturdy populations that the tourist discovers in the heart of a remote province, and that have piously preserved the costume, habits, and traditions of their ancestors through revolutions and wars. Among the mammals that subsist as relics of the past, we may mention the water mole (*Ornithorhynchus*), the porcupine ant-eaters (*Echidnæ*), the kangaroo, the elephant, the rhinoceros, the hippopotamus, and, finally, the ant-eaters of the genus *Myrmecophaga*, which will form the subject of this article. Like the *Orycteropi*, the ant-eaters belong to the curious order of *Edentata*, which contributed to the ancient fauna the gigantic *megatherium* and the huge *glyptodon*, and which still includes among its representatives the sloths, armadillos, and pangolins; but they are distinguished from all the animals just cited by their external form as well as by various osteological peculiarities. In the ant-eaters, in fact, the skin is neither bare, as in the earth pig (*Orycteropus*), nor covered with imbricated scales, as in the pangolins, and is not encrusted with bony concretions, as in the armadillos, but disappears under a thick coat of hair, as in the sloths. The coat, however, is not so rough and coarse as in the latter. The head, instead of being globular, is prolonged in front into a pointed muzzle, and the body terminates behind in a bushy tail. On another hand, the maxillary bones are slender and entirely deprived of teeth, so that the animals more justly merit the name of *Edentates* than do the *Orycteropi*, whose jaws are provided with organs of mastication, at least in their posterior half.

The ant-eaters are met with only in South America. There are three species known, and these differ so much from each other in size and the nature of their coat that modern naturalists have thought it necessary to distribute them among two or three genera instead of leaving them confounded in a single group (*Myrmecophaga*), as Linnæus did. Of these three species, designated vulgarly as the giant ant-eater, the tamandua and the two-toed ant-eater, the first only, the giant ant-eater (*Myrmecophaga jubata*), is to occupy us in this place. It was figured more or less rudely two hundred and fifty years ago in J. De Laet's Descriptions of the West Indies, and in Margraff and Lieb-

stadt's Natural History of Brazil; but it is especially in the Narrative of the Voyage of Chevalier des Marchais, published in 1731, that we find a singularly accurate description of the ant-eater, considering the epoch at which it was published.

"At Cayenne," says the chevalier, "there is an animal called the ant-eater, that might be styled the American fox were it found in America only; but, as there are others in Africa, I believe that it is necessary to stick to the first name, unless we desire to use the very long one that is given the animal by the Indians, who call it *tamadu guacu*, which means 'ant-eater.' It is its usual food that has given it its name.

"This animal is as long and as large as a good sized dog. Its hind legs are shaped like those of a bear; the fore legs are not so large. It has a flat foot, with four toes armed with long and sharp nails. The hind feet have five well armed toes. Its head is long and its muzzle is still longer and pointed. It has two small, round, black eyes, and very short ears. Those who have taken the trouble to measure its tongue say that it is two feet in length, and sometimes longer. It is obliged to bend it in order to conceal it in its mouth, which, as long as it is, would not suffice to conceal this organ. Could it speak, it would doubtless talk a good deal, and it would be censured, not without reason, for having 'too much tongue.'

"It lives upon ants. When it discovers a retreat of the latter, it digs with its nails in order to widen the entrance and reach the center of the ant hill; it then immediately thrusts into it its long tongue, which reaches every corner of the cavity, and, as it is unctuous, the ants, frightened and in disorder, at once adhere to it. As soon as it feels that its tongue is charged with these insects, it draws it into its mouth and swallows them. It continues this operation as long as it perceives any insects in the place, and, after this, if it is still hungry, it goes off to seek another hill. This, as may be seen, is slim food, and yet, for all that, it well nourishes the animal that makes use of it, although it gives its flesh an odor of ants that is not agreeable. The Indians and negroes eat it, but the French have better meats. If they knew their interests a little better, they would carefully preserve these animals, which would deliver them wholly or in part from ants, which do them great injury. My recollection does not recall whether the animal likes white ants as much as it does the black ones. The white ants are known under the name of wood lice, which they somewhat resemble in form. . . . They are equally injurious everywhere. It would be an extreme good fortune for the inhabitants if they were rid of these noxious insects, which are still more pernicious than the black ants. To this event hunters should be strictly forbidden to do the ant-eaters any injury.

"I have said that they might be called foxes. It is to their tail that they would be indebted for this title. In fact, there is no fox in the world that has so supple a tail as they have. It is often nearly two feet in length. It is nearly flat and covered on every side with hairs from 15 to 20 inches in length, and which, in truth, are somewhat coarse, thus giving the tail somewhat the appearance of that of the horse. As it is strong, and the animal gives it any motion that it pleases, it sweeps the places where it passes, and when it turns it up over its back it covers the latter with it entirely. It thus protects its back against the rain, which it greatly dreads. . . . ."

FIG. 1.—THE GIANT ANT-EATER.

(From an engraving of the seventeenth century.)

There is, in truth, very little to add to the description. Chevalier des Marchais, however, does not seem to have dealt sufficiently upon the conformation of the ant-eater's paws. The hind ones, which have five toes provided with pointed nails, are in fact notably weaker than the fore ones, which terminate in four toes armed with huge claws that are curved and sharp like a sickle. It is by means of these claws that the animal tears ant hills open, and it is with these weapons that it defends itself against its enemies, which it strikes laterally by throwing back the limbs with a horizontal motion. The front limbs are in fact slightly twisted—an arrangement well adapted for the principal purpose that they have to fulfill, but very unfavorable for locomotion. So the ant-eater has an awkward gait, and, in walking, is obliged to support itself upon the lateral face of the fore feet, or rather to keep its fore toes and claws bent up against a callous cushion of the palmary surface.

The form of the ant-eater's head denotes an animal of feeble intelligence; in fact, it has an extremely retreating forehead and the cerebral region is depressed and but slightly developed in proportion to the facial region, which is prolonged into a long muzzle slightly recurved in front and provided with semicircular nasal apertures. The ears are reduced to two roundish membranes, 12 inches in length. The eyes are scarcely larger than a juniper berry, and the mouth is so narrow that it seems scarcely capable of allowing of the passage of the tongue, and the mean diameter of which does not exceed $\frac{3}{4}$ of an inch in the center and $\frac{3}{16}$ at the extremity.

As Chevalier des Marchais accurately observed, the giant ant-eater's tongue, like that of the tamandua, the earth pig and other edentates, constitutes much less an organ of taste than one of prehension. It is moved by powerful muscles, and although it is not, when in a state of rest, bent up in the mouth, but simply compressed against the jaws, at the side of the pharynx, it can, like the tongue of the woodpeckers, be suddenly thrust out and be projected to a distance that Roulin estimates at seventeen inches. Its surface is coated with a glutinous saliva which is secreted by submaxillary glands of extraordinary dimensions, extending to the breast, and the structure of which has been studied by Sir Richard Owen and Mr. G. Pouchet, and which have been found also by Mr. J. Chetin in the tamandua. On the contrary, the parotid glands, which furnish an aqueous saliva, are considerably reduced in size in the ant-eaters.

The absence of teeth in these animals offers no inconvenience as regards nutrition, since the insects upon which they prey do not possess strong teguments, and are capable, moreover, of being triturated in the stomach. The latter, in fact, consists of two distinct parts, viz., of a cardiac or membraneous part and of a pyloric or muscular one, which, as regards the strength of its parieties, may be compared to the gizzard of birds, although it is not provided with epithelial callosities.

Mr. Owen has found, on the one hand, that the intestine of the ant-eaters is supported, as in reptiles, by a large fold of the peritoneum, and Mr. Crisp has been struck with the exceptional dimensions that the blood globules attain in the same species. The mean diameter of these, which does not exceed $\frac{1}{3200}$ of an inch in man, reaches $\frac{1}{2800}$ in the ant-eaters.

These animals are noticeable again by the size of their biliary vesicle, by the thickness of their teguments, by the development of their cutaneous muscles, by the width of their ribs, which lap over each other, and especially by the conformation of their brain, which exhibits a pretty degraded type. The hemispheres, which are connected by a wide callous body, leave the cerebellum exposed, in fact, and exhibit upon their surface but a small number of symmetrical convolutions. On the contrary, the olfactory lobes are very large, as in all animals possessing a delicate sense of smell. The sense of smell, in fact, is the only sense that is well developed in the ant-eater.

The coat of the giant ant-eater is extremely shaggy. The end of the muzzle, the lips, the eyelids and the soles of the feet are the only bare parts, and the head, body and limbs are covered with hair, which in length, thickness and color differs from one region to another. Upon the head, the hair is short and erect, of a gray color, with black rings; upon the back, it is long and silky and of the same color; and upon the nape of the neck it rises and forms a mane from eight to ten inches in length. The hair of the sides and buttocks is softer and less erect, while that of the tail is stiff and more or less flattened. The hind paws and the belly are of a dark brown; the back and the tail are of an ashen gray, speckled with black; the head is gray, with a white stripe on each side of the forehead; the fore paws are ornamented with a circular stripe interrupted behind; and the throat is covered with a blackish plastron prolonged laterally by a stripe of the same color with a whitish edge, which meets the shoulders obliquely and ends in a point on the side of the spine. Upon the parts destitute of hair, the skin is of quite a dark tint. The same system of coloration exists in the young animals, although the latter as a general thing exhibit a paler color than that of the adults.

The giant ant-eaters are found in the region east of the Andes comprised between the Rio de la Plata and the Caribbean Sea, but they are particularly common in the desert or sparsely peopled regions of the north of Paraguay. They generally live isolatedly, and when two individuals are found in company it is almost always a female accompanied by a young one. The young animal is in fact suckled for a very long

FIG. 2.—GIANT ANT-EATER DEFENDING ITSELF AGAINST A JAGUAR.

time, and remains in the company of its mother until she is about to bring forth a second time. The giant ant-eater does not dig a burrow, and has no fixed abode. After wandering all day through the plains in search of ants or termites, it contents itself at nightfall with the shelter of a bush, or simply goes to sleep wherever it chances to be, amid tall grasses. When at rest, it resembles, it is said, a bundle of hay lying upon the ground. Its ordinary gait is very slow, and it is only when it is pursued that it begins a clumsy gallop. Still it does not move quickly enough to prevent a man walking at a good pace easily to overtake it.

Usually, the animals are perfectly harmless, but when they find themselves too close pressed, and especially when they are wounded, they do not hesitate to face the enemy. They then stand upon their hind legs after the manner of bears, and, growling with anger, extend their arms and endeavor to strangle their adversary or to lacerate it with their claws. And it may be easily imagined how terrible are the wounds made by nails as sharp as razors and measuring from 1½ inches to 3 inches in length, especially when these nails arm a powerful paw at the extremity of a strong limb. Thus the traveler Roulin came near being cut to pieces by an ant-eater that he had imprudently seized by the tail in order to stop the animal while running to escape the whip of a young shepherd who had surprised it near an ant-hill. The ant-eater, turning about, swept the air with a sudden motion, and Roulin saw pass, at two inches from his waist, a nail that appeared to him to be six inches in length, and that would have ripped open his abdomen from one side to the other had he taken another step. Later on, even, after the exhausted beast had been seized with a lasso, it still tried to resist by lying upon its back and flourishing its limbs.

Ant-eaters, wounded by troopers, have been observed to hang on to the crupper of a horse, and not let go until after receiving several stabs from a spear; and the inhabitants of Colombia and Paraguay assert that these edentates wage desperate conflicts with jaguars that usually terminate in the death of both combatants. It is said that the dead bodies of the adversaries are sometimes found in a close embrace. Although he had never been a witness of such things, Roulin does not consider these stories as devoid of truth. In fact, he observes that although the jaguar does not usually allow the prey that it covets time to recover itself, and although it usually reaches it in two or three leaps and instantly throttles it, it may also miss its object and find itself in a pretty critical situation. In such an event, the ant-eater will have time to get on its legs.

As shown in Fig. 2, it will sit squat and threaten its enemy, and, as soon as the latter springs, will clasp it between its powerful arms and lacerate it with its powerful claws, while its own bones may be crushed between the terrible jaws of the carnivore.

An ant-eater easily manages a dog of large size, but cannot resist a man armed with a gun. The hunting of this animal, therefore, presents no great danger, and ought, then, to offer so much the less attraction (as Des Marchais remarks), in that the ant-eater is an eminently useful creature, and that its flesh has a very disagreeable taste of ants. Yet the inhabitants of Paraguay annually destroy a large number of the giant ant-eaters, which they designate by the name of *gnouroumys* or *youroumys*, and whose skin they use as bed coverings, it being, they say, excellent for preventing kidney diseases. Individuals of this species are also sent alive to Europe in order to be kept in zoological gardens. However, it is merely through the oddity of their form that they merit a place in menageries, for, like the oryeteropi, they are indifferent and stupid beasts.—*E. Onstalet, in La Nature.*

[FROM THE MEDICAL COURANT.]

HYDRASTIS VS. PHTHISIS.

By A. JUDSON PALMER, M.D.

ABOUT one hundred years ago William Cullen defined phthisis as "an expectoration of pus or purulent matter from the lungs, attended with a hectic fever." Later the tubercle was discovered, and it was found that this tubercle contained a virus. In the year 1882 the tubercle bacillus was discovered by Koch. It is now generally conceded that tuberculosis, whether of the lungs or other tissues, is coincident with the presence of these microphytes. The important consideration, then, is how to exterminate these pathognomonic germs, or prevent the putrefactive process which they induce.

I have used hydrastis in my practice for the past thirty years as a local application to inflamed mucous surfaces, and noting its efficiency, especially in inflammatory conditions of the pharynx, it occurred to me that it might be equally efficacious in the treatment of bronchitis if it were possible to apply it directly to the inflamed membrane. Accordingly, about four years ago, to accomplish this I administered it by inhalation in the form of a vapor, freed from spray, and thus secured its deposit where required. The result was very satisfactory. I then used it in a case of bronchitis complicated with chronic hepatization, due to incomplete restoration from an attack of pneumonia which had occurred two months previously. I was surprised to find that not only the bronchitis but also the pneumonic deposit disappeared. I then determined to test its virtue in phthisis. I have now been using it in the different stages of this disease over three years, and I think the result of my experience justifies me in asserting that in it I have found a remedy of remarkable efficacy in the treatment of phthisis, if properly and perseveringly used; and that the majority of cases, while in the early stages, can thus be restored to a condition of apparent health.

Precisely in what manner its extraordinary influence is exerted is a question upon which opinions may differ, but I have demonstrated to my own satisfaction that in some way it has a decidedly specific action upon this disease.

During the first month of treatment the night sweats usually disappear, and the cough and expectoration are greatly diminished; the patient has a better appetite, better digestion, and gains in strength.

In cases advanced so far as to be incurable, the patients are so much relieved that they regard the remedy as indispensable to their comfort. Its hæmostatic properties render it of great value as a preventive of hemorrhage.

I obtain the best results by using it in combination with chloride of sodium, one part of the fluid extract of hydrastis can. to three parts of a saturated solution of the salt.

The fact that I use it in conjunction with salt may lead to the supposition that salt is the principal agent in effecting the cure; but I have obtained the same results by using it mixed with glycerine and water.

The volume of vapor should be moderate at first and gradually increased from day to day as the patient becomes accustomed to its use, after which I advise deep inspirations to insure the entrance of the vapor to the remote air cells. When patients are taking the inhalations at their homes, the physician should visit them sufficiently often to watch the effect of the treatment and to advise in regard to the strength of medicine and the volume of vapor.

In most cases I continue the inhalations once or twice daily until I observe a decided improvement, after which I regulate the frequency according to circumstances.

Care, of course, should be taken to place the patient under as favorable hygienic conditions as possible.

90 Hancock Street, Brooklyn, N. Y.

IT appears from a report made by Professor Hazen, of the Signal Service, that the average number of person killed annually in the United States by tornadoes during the last eighteen years is 182. This mortality appears to be less than that from lightning strokes. It further appears that in no State may a destructive tornado be expected oftener than once in two years on an average. The territory affected is usually both short and narrow.

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